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E L E M E N T S
O F
N A T U R A L H I S T O R Y,
A N D O F
C H E M I S T R Y:

BEING THE SECOND EDITION OF
THE ELEMENTARY LECTURES ON
THOSE SCIENCES,

FIRST PUBLISHED IN 1782,

A N D N O W

GREATLY ENLARGED AND IMPROVED,

By THE AUTHOR, *M. DE FOURCROY*,

DOCTOR OF THE FACULTY OF MEDICINE AT PARIS,
OF THE ROYAL ACADEMY OF SCIENCES, &c. &c. &c.

TRANSLATED INTO ENGLISH.

WITH OCCASIONAL NOTES, AND AN HISTORICAL
PREFACE, BY THE TRANSLATOR;

VOL. I.

L O N D O N:

PRINTED FOR G. G. J. AND J. ROBINSON,
PATER-NOSTER-ROW.

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E L E M E N T S

NATURAL HISTORY

C H E M I S T R Y

THE ELEMENTARY LECTURES ON
THOSE SCIENCES



TRANSLATED INTO ENGLISH
WITH OCCASIONAL NOTES AND AN APPENDIX
PREFACE BY THE TRANSLATOR

VOL. I

L O N D O N
PRINTED BY C. & J. JOHNSON
STATIONERS-HALL-COURT
NEAR ST. MARTIN'S

THE TRANSLATOR'S PREFACE.

THE importance of chemical knowledge to society, and the favourable reception which the following work has met with among our enlightened neighbours, render it unnecessary to mention the motives that have caused an English translation to be undertaken. A very few words will likewise be sufficient to explain the manner in which I have endeavoured to perform my duty as translator. The original has been as closely followed as the genius of the two languages would permit; and in such places, as a greater liberty has been taken, it will be invariably found, that the single purpose of adhering with fidelity to the author's meaning has been strictly kept in view. I have likewise added some Notes, which I hope will be found useful. In these I thought it incumbent on me, as the book is intended for beginners, to avoid all controversial remarks on the theoretical doctrines contained in the text: neither did I suppose it at all necessary that I should enter into historical discussion. But as it is certain, that the want of a speedy and faithful communication of philosophical discoveries between Great

Britain and the Continent, together with the unprincipled conduct of such persons as are daily employed in endeavouring to appropriate to themselves the discoveries of others, have produced many historical mistakes; and on the other hand, as among the variety of new theories of chemistry, offered to the public, few have been exhibited with a proper discrimination between hypothesis and matter of fact; I presume that a short account of some of the principal changes, the science of chemistry has undergone of late years, will not be unacceptable.

In the infancy of the true philosophy, when the same men who had been taught the logomachia of the schools began to draw inferences, and to reason from the things around them, it is not to be wondered that their reliance on the power of the human mind was greater than it ought to have been, and that they were not aware of the necessity of often recurring to the test of experiment, in order to detect the unwarranted conclusions we are continually making. A few first principles, possible indeed, but not proved, were assumed by the great Des-Cartes as a foundation for a complete theory of the universe. From these he deduced such facts as were known in his time. The facility with which the author of a favourite hypothesis can adapt the facts to it, was not then known; and therefore he thought it a good argument
to

to urge his success, * as a proof of the truth of his principles. The philosophers, who have succeeded him, have been but too much inclined to follow his example. Where the principles existing in nature are but few, as is the case with mechanics, the greatest success has followed the application of strict mathematical reasoning to those principles; but in chemistry, where they are perhaps numerous, and certainly in many respects unknown, the imperfect theories, and the numerous paralogisms, with which the writings of philosophers are filled, often induce the cautious reader to wish that they had been either less ready in making their inferences, or more attentive to the strict verification of them by experiment.

The operations of chemistry, taken in a loose and general sense, consist in the producing changes in bodies, either by heating them, or by presenting them to other fluid bodies, with which they form an union. And as combustion is the most usual means of raising the temperature of bodies, the most important part of chemical science must consist in a knowledge of what happens in

* Sed qui advertent quam multa de magnete, de igne, de totius mundi fabrica, ex paucis quibusdam principiis hic deducta sint; quamvis ista principia tantum casu & sine ratione à me assumpta esse putarent, forte tamen agnoscent, vix potuisse contingere, ut tam multa simul cohererent si falsa essent. Principia sub fine.

that wonderful process. The early chemists among the moderns, borrowing their terms from such substances as appeared eminently to possess certain properties, supposed combustibility to depend on a sulphur contained in bodies. This opinion was rectified, and generalized by Beccher, and afterwards by Stahl; their doctrine being simply, that combustible bodies contain a principle called phlogiston, which unflammable bodies do not, and that combustion consists in the escape of this principle.

The opinion, that a principle escaped from bodies during combustion, coincided perfectly with the common notions derived from the ascent of smoke, flame, &c. and the comprehensive and truly philosophical genius of Stahl, was applied in adapting it, with so happy a facility, to the leading phenomena of chemistry, that it became universal throughout Europe. Difficulties were indeed urged against it, the chief of which were, that the principle of inflammability had never been exhibited alone, and that such bodies as did not emit vapours in sensible quantities, were found to be augmented, instead of diminished in weight, by the imaginary loss of one of their principles. But these were supposed to be removed, by the observation that phlogiston never quitted an inflammable body, but to unite with another of the unflammable class; and the additional weight, gained

ed by calcined metals, was by some supposed to consist in the matter of fire, and by others to arise from the property of absolute levity, which they attributed to phlogiston.

The numerous discoveries of Dr. Priestley have directed the attention of philosophers to the properties of bodies in the aerial or permanently elastic state; and in the rich harvest of discovery which has followed, that great man has continued to maintain the pre-eminence in which his first fame originated. It was from his experiments that Mr. Kirwan deduced the opinion that inflammable air, in a state of combination, is the very substance to which all the characters and properties of the phlogiston of the ancient chemists belong; and this opinion was rendered still more probable by a subsequent series of experiments, in which Dr. Priestley revived metallic calces, by heating them with a burning glass in inflammable air.

A considerable number of modern philosophers had observed the necessity of air to maintain combustion; but Dr. Priestley first made experiments directed to this object. His capital discovery of pure, vital, or dephlogisticated air, is of the highest value.*

M. La-

* Dr. Priestley discovered this air on the first of August 1774, (see his 2d vol. p. 34.) and ascertained its properties in the course of the following year. The celebrated Scheele, whose loss is severely felt by the scientific world,

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M. Lavoisier is the first who, by direct and accurate experiments, proved that the weight gained by metals in calcination, corresponds with that of the air they absorb. This circumstance, together with the discovery of the composition of water, seems to have given the doctrine of phlogiston a shock, at least equal to the advantage it derived from the discovery of the revival of metallic calces by inflammable air. For it was an inference easily made, that if metals, and other substances, were admitted to receive air in calcination, and to recover their inflammability by giving it out, it was unnecessary to suppose a principle of inflammability.

The powers of nature, which are ever the same, and are continually performing their operations before us, whether we understand them or not, often present facts of the utmost value and importance, which we overlook, or regard with indifference. Hence it happens, that when an enlightened observer makes any discovery, it is almost always

made the same discovery before the middle of the year 1775, Dr. Priestley's book not being then published. Scheele's treatise on air and fire was not published till the latter part of the year 1777. There is no doubt but these two great philosophers made their discoveries independent of each other, and without the knowledge of the obscure hints respecting this kind of air, which John Mayow gave, almost a century before. Consult pages xiii. and xl. of the preliminary matter to the English translation of Scheele's *Chemical Observations on Air and Fire*, by J. R. Forster, L.L.D. &c.

observed

observed that somebody has seen the fact before him, or given some confused hints respecting its theory. It is evident, however, that the first discoverer, if there be any merit in discovery, is not the man who finds the treasure, and supposes it to be none; but him who is conscious of its value, and applies it to use. On these principles it is, that the claims of the discoverers of the composition of water must be estimated. The facts appear to be as follow.

Previous to the month of October 1776, the celebrated Macquer, assisted by M. Sigaud de la Fond, made an experiment by burning inflammable air in a bottle, without explosion, and holding a white china saucer over the flame. His intention appears to have been that of ascertaining whether any fuliginous smoke was produced; and he observes that the saucer remained perfectly clean and white; but was moistened with perceptible drops of a clear fluid, resembling water, and which in fact appeared to him, and his assistant, to be nothing but pure water. He does not say whether any test was applied to ascertain this purity, neither does he make any remark on the fact.*

In the month of September 1777, Messrs. Bucquet and Lavoisier, not being acquainted

* Dictionnaire de Chymie, 2d Edition, Paris, 1778. Art. Gas Inflammable, Vol. II. p. 314, 315.

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with the fact, which is incidentally and concisely mentioned by Macquer, made an experiment to discover what is produced by the combustion of inflammable air. They fired five or six pints of inflammable air in an open and wide-mouthed bottle, and instantly poured two ounces of lime-water through the flame, agitating the bottle during the time the combustion lasted. The result of this experiment shewed that fixed air was not produced.*

Before the month of April 1781, M. John Warltire, encouraged by Dr. Priestley, fired a mixture of common and inflammable air in a close copper vessel, and found its weight diminished. Dr. Priestley likewise, before the same period, fired a like mixture of inflammable air and common air, and also of inflammable air and dephlogisticated air, in a closed glass vessel, Mr. Warltire being present. The inside of the vessel, though clean and dry before, became dewy, and was lined with a sooty substance.† These experiments were afterwards repeated by Mr. Cavendish, and by Dr. Priestley, and it was found that the diminution of weight did not take place, neither was the sooty matter perceived.‡

* Acad. Par. 1781, p. 470.

† Priestley, V. 395.

‡ Phil. Transf. LXXIV. 126. Dr. Priestley supposed the sooty matter to be part of the mercury used in filling the vessel. Phil. Transf. LXXIV. 332.

These

These circumstances, therefore, must have arisen from some imperfection in the apparatus or materials, with which the former experiments were made.

It was in the summer of the year 1781, that Mr. Henry Cavendish was busied in examining what becomes of the air lost by phlogistication, and made those valuable experiments which were read before the Royal Society on the 15th of January, 1784.* He burned 50000 grain measures of inflammable, with about $2\frac{1}{2}$ times the quantity of common air, and by causing the burned air to pass through a glass tube, eight feet in length, 135 grains of pure water was condensed. He also exploded a mixture of 19500 grain measures of dephlogisticated, and 37000 of inflammable air, in a close vessel. The condensed liquor was found to contain a small proportion of nitrous acid, when the mixture of the air was such that the burned air was not much phlogisticated. This great philosopher, who may be considered as the true discoverer of the composition of water, appears to think, with Mr.

* Mr. Lavoisier relates, that Dr. Blagden, Sec. R. S. (who was present at the performing of the capital experiment of burning inflammable and dephlogisticated air in a closed vessel on the 24th June, 1783) informed him, that Mr. Cavendish had already done the same thing, and obtained water. See the Memoirs of the Royal Academy at Paris, for 1781, p. 472. also Phil. Trans. vol. lxxiv. p. 134.

Watt,

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Watt, that in those experiments of Dr. Priestley's, in which the vitriolic and nitrous acids seemed to be converted into dephlogisticated air, the acids served only to decompose the water by depriving it of its phlogistic part; but he thinks it unnecessary to include the consideration of elementary heat, as Mr. Watt does, because, in his opinion, it is more likely that there is no such thing, and that the bringing the consideration forward in every chemical experiment, in which increase or diminution of heat takes place, might occasion more trouble and perplexity than it is worth.*

In the mean time M. Lavoisier continued his researches, and during the winter of 1781—1782, together with M. Gingembre, he filled a bottle of six pints with inflammable air, which being fired, and two ounces of lime-water poured in, was instantly stopped with a cork, through which a flexible tube communicating with a vessel of dephlogisticated air was passed. The inflammation ceased, except at the orifice of the tube, through which the dephlogisticated air was pressed, where a beautiful flame appeared. The combustion continued a considerable time, during which the lime-water was agitated in the bottle. Neither this, nor the same experiment repeated with pure water,

* Philosoph. Transf. vol. lxxiv.

and with a weak solution of alkali, instead of lime-water, produced the desired conclusion; for these substances were not at all altered.

The inference of Mr. Warltire, respecting the moisture on the inside of the glass, in which Dr. Priestley first fired inflammable and common air, was, that these airs by combustion deposited the moisture they contained. Mr. Watt, however, inferred from these experiments, that water is a compound of the burned airs, which have given out their latent heat by combustion; and communicated his sentiments to Dr. Priestley in a letter, dated April 26, 1783,* and he concludes, that in every case wherein dephlogisticated air was produced, water has been decomposed, by the use of some substance which had a stronger attraction to its phlogiston than is possessed by the dephlogisticated air, which is therefore set at liberty. He repeated some experiments particularly with a view to decide this point, and in several of them the quantity of dephlogisticated air added to the acid which came over, greatly exceeded the original weight of acid employed. He dissolved magnesia, calcareous earth, and minium respectively in pale nitrous acid, and on distilling to dryness, found nearly the whole of the nitrous acid

* Philosoph. Transf. vol. lxxiv. p. 330.

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in the retort, highly phlogisticated. From common nitre the dephlogisticated air was sixteen times the weight of the nitrous acid which was missing. Mr. Watt has therefore a claim to the merit of a discoverer with regard to the composition of water, and has the advantage of priority in the discovery of its decomposition.

It does not appear* that the composition of water was known, or admitted in France, till the summer of 1783, when M. Lavoisier and M. de la Place, on the 24th of June, repeated the experiment of burning inflammable and dephlogisticated air in a glass vessel over mercury, in a still greater quantity than had been burned by Mr. Cavendish. The result was nearly 5 || gros of pure water. M. Monge] made a similar experiment at Paris, nearly at the same time, or perhaps before.

The theory which has been proposed and explained by M. Lavoisier, wherein such phenomena as chemists have usually accounted for by the disengagement or transition of phlogiston, are explained, merely by the engagement or contrary transition of dephlogisticated air, or its base, by him called

* Compare Phil. Transf. vol. lxxiv. p. 138. with the Memoirs of the Royal Academy at Paris for 1781, pages 472, and 474.

|| The ounce poids de marc being 472. 2 gr. troy, this quantity will be 295 English grains.

the

the oxygenous or acidifying principle, is amply explained in the following work. This theory received a great accession from the discovery of the composition of water, as I have already remarked; for it was easy to attribute the inflammable air which is disengaged in many processes to the decomposition of water, which is undoubtedly present in most of them, instead of supposing it to come from such bodies as former chemists had imagined to contain the principle of inflammability. In the month of September, 1783, M. de la Place communicated to M. Lavoisier his thoughts† on the decomposition of water, which from M. Lavoisier's former experiments he concluded to take place in metallic solutions; and these reasons, added to M. Lavoisier's own reflections, induced him to pursue the subject by a new series of experiments.

This assiduous and accurate philosopher first placed a quantity of iron filings and pure water in the upper part of a vessel inverted over mercury, and observed that the iron became calcined, inflammable air being at the same time disengaged, the water being, as he says, truly decomposed.* He then proceeded, in conjunction with M. Meusnier, to pass the steam of water through a red hot iron tube, and found that the iron

† *Memoirs of the Royal Academy at Paris*, 1781, p. 476.

* *Ibid.* 1781, p. 271.

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was calcined, and inflammable air disengaged: and the steam of water being passed over a variety of other combustible or calcinable substances, produced similar results; the water disappearing, and inflammable air being disengaged. These capital experiments are accounted for by M. Lavoisier, and such chemists as do not admit the existence of phlogiston, by supposing the water to be decomposed into its component parts, dephlogisticated and inflammable air, the former of which is said to unite with the ignited substance, while the latter is disengaged. If it were allowable to place much dependance on the quantities of the products in experiments of this nature, wherein different philosophers disagree, the results of M. Lavoisier, which answer to the proportions of the two principles determined in the composition of water, would add much force to his conclusions. But the advocates for phlogiston contend, that the water unites totally with inflammable or calcinable substances, and sets their phlogiston at liberty. If the chemical reader will attentively peruse the valuable papers of the Anti-phlogistians in the *Journal de Rôzier*, and the *Memoirs of the Royal Academy at Paris*, and compare them with *Kirwan's Treatise on Phlogiston*, *Dr. Priestley's 6th volume of Experiments and Observations*, and more especially with the latter part of *Mr. Cavendish's paper in the*

74th volume of the Philosophical Transactions, which is a master-piece of precision and clearness, he will see that the deductions respecting the existence or non-existence of phlogiston in the sense of Stahl, are very far from being conclusive, because decisive experiments are wanting. He will also perceive, that the nomenclatures of the old and new chemistry, founded on their respective theories, are so interwoven into the relation of matters of fact, as to have produced numberless paralogisms on either side; and that nothing is easier, in general, than to account for chemical phenomena either way.

When the extensive nature of chemical science is attended to, we have more reason to admire the rapid success of our co-temporaries, than to censure their errors; but silence is equally blamable, because it tends to perpetuate them. I shall therefore conclude this preface by observing, that I have not, in the subordinate, though useful, office of translator, been forgetful of that respect which is due to the writer, whose work I have thought proper to turn into English. I have advanced no opinions of my own; neither have I indecently controverted his positions. It appeared necessary to state the facts I have here mentioned, and it will be seen that I have stated them with fidelity. And as I have displayed none of that mean national

VOL. I. * b partiality,

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partiality, which combined with the difficulty of acquiring a perfect knowledge of what passes in foreign countries, too often produces misrepresentations of facts, I am persuaded that the candid among our neighbours, as well as the learned author himself, will receive it with a proper degree of liberality.

LONDON, Dec. 13. 1787.

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PRELIMINARY DISCOURSE.

Containing a short Account of the Nature and Properties of Elastic Fluids, and serving instead of Additions and Corrections, to the Facts and the Chemical Theory contained in this Work.

ALthough the new discoveries made since the end of the year 1781, the time of the publication of the first edition of this work, have rendered it necessary to make considerable alterations and additions in this second edition; yet the time of its going to the press has not admitted of the insertion of many very important facts relative to chemical theory; more especially in the places they ought properly to have occupied in the order of the work. I have therefore thought proper to give a view of the whole, that such as are desirous of entering into the study of chemistry may not be deprived of them. It is not my intention to give an ample detail of all the new enquiries in which modern chemists are engaged, be-

cause they would much exceed the limits of a supplement, but I have not neglected any facts that considerably influence the theory of chemistry; and as several of these are such as have even caused me to change my opinion with respect to some of the general theories proposed in this work, I have thought proper to give the new facts in a connected manner, under the title of an Account of the Nature and Properties of Elastic Fluids.

Modern chemists have given the name of elastic fluid or gas to bodies which have the appearance of air, though they do not possess all its properties; but when the history of all permanently elastic fluids is attended to, atmospheric air is usually comprehended amongst them.

Since the time it has been clearly ascertained that, in a great number of chemical operations, many of these elastic fluids are either disengaged or fixed, the attention of philosophers has been directed to the study of their different properties, and many attempts have been made to determine what influence their disengagement or fixation may have on natural phenomena.

Many persons, in other respects very eminent, have hastily adopted the opinion, that these bodies are nothing more than common air, mixed or impregnated with different matters in a vaporous form. In consequence

quence of this notion, they have decidedly asserted that these fluids have been too much attended to, and that their newly discovered properties ought not to be considered as having any influence on chemical theory. We ought not to be surprized at finding this repugnance, and even opposition, amongst the learned, to the reception of these new doctrines, when we reflect, that Stahl, one of the greatest geniuses of his age, entertained the same opinion respecting the discoveries of Hales on Air. This difficulty of admitting a theory so very different from that of the ancients, may likewise arise from the circumstance that the greater number of the works in which this part of chemical science is treated of, have not given a very accurate statement of the general nature, formation, and fixation of these elastic fluids. The theory which respects them has not yet been clearly developed, but in some particular memoirs of Mr. Lavoisier; and the history of gases has never yet been collected into one work. But as this subject is one of the highest importance, and relates to a great number of phenomena, which the early time of the impression of the first volume of this work has not permitted me to insert at that length, and with that perspicuity it deserves, it becomes necessary to consider it in this place.

§ 1. Concerning Light and Heat, and the Formation, Disengagement, and Fixation of Elastic Fluids.

It is, at present, universally acknowledged that light is a body, existing independent of all other substances, and possessing its own characteristic properties. As to heat, the proofs of its existence are not so well established; and many philosophers have thought that it was nothing more than a modification, which all bodies are susceptible of; but the modern experiments on the different quantities of heat contained in bodies, their aptitude to absorb, to preserve, or to conduct heat, and the elective attractions which it seems to follow, render the first opinion concerning its existence much more probable than ever; and it is certain that all the phenomena observed in nature, are more easily and naturally explained according to this opinion, than by that of Bacon. It will therefore be proper to shew in this discourse, first, the reasons which induced me to prefer this hypothesis to that which I have adopted in the first volume of this work. 2dly, The modifications which this new hypothesis must produce in the principal theories of chemistry.

The

The simple and uniform laws, by which nature appears to produce the phenomena we behold around us, seem to point out that there is but one body which can be considered as fire; for this reason, many modern philosophers consider light and heat as one single fluid, as pure fire, but in two different states; it is light when the particles collected together, and in possession of their whole attractive force unsaturated, are projected with immense velocity; it is heat when these same particles dispersed, and divided more slowly, and with a tendency to equilibrium. According to this theory, heat may become light; and light, on the other hand, may become heat, when this motion is rendered sufficiently slow. It cannot, however, be denied that light often produces effects very different from those of heat, as is seen in the nitrous acid, aerated muriatic acid, metallic calces, and the leaves of vegetables; all which give out vital air when exposed to the sun's rays, though heat alone has no effect in disengaging that fluid from them. Thus it is likewise found that the light of the coals, which passes through vessels ignited in the fire, changes the nature of the products, as was first observed by myself in the former edition of this work. Modern chemists admit heat as a principle, and inform us that all natural bodies contain dif-

ferent quantities of this fluid. One of the principal effects of this combined heat, which all bodies seem capable of containing in different quantities, in their different states of aggregation, is to change and to modify the states of bodies. In order to understand this phenomenon, it must be observed, that there are two kinds of heat, or rather, that heat itself exists in two different states in all natural substances; the one a state of intimate combination, in which heat is called latent, because it is not sensible; the other state is that in which it is simply diffeminated: heat in this last state may be driven out by pressure alone, or by mechanical means. Thus it is that when a bar of iron is struck, and its particles are by that means made to approach each other, part of its heat escapes in the same manner as water issues out of a wet sponge. Heat, in a state of true combination, does not leave the body it is combined with, but in consequence of new chemical combinations. All solid matters, which contain these two kinds of heat, are capable of receiving a greater quantity both of one and of the other, and the additional quantity causes the particles to recede more and more from each other. Its first effect is the softening of the solid body; its second, in proportion as its quantity becomes greater, is fusion or liquefaction; its
third,

third, still supposing an augmentation of quantity, is the production of elastic fluidity. Thus water in the form of ice is softened by a certain degree of heat, as appears by its being less elastic; a greater degree of heat melts it; and lastly, it becomes still more fluid, if the term may be used, when a stronger degree of heat reduces it into vapour: so that the vapour of water may be said to contain a total sum of heat, consisting of the quantity necessary to constitute ice of a certain density, added to the quantity necessary to produce the state of liquidity; and lastly, the quantity necessary to maintain the state of elastic fluidity.

This general theory may be applied to all the bodies in nature; there is no one which may not be considered as capable of passing through all these states by the assistance of a sufficient degree of heat, and as far as relates to this property, they do not appear to differ from each other, but in the quantities of heat necessary to produce the changes respectively in each. It is for want of a sufficient degree of heat, that rock crystal can neither be melted*, nor brought into the vaporous state; and it is no more difficult to conceive the possibility

* See note on p. 217. vol. I.

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of this being effected, than it is to conceive that the fluid we always see in a state of elasticity, namely, the air may acquire a great degree of solidity, as in fact happens in many combinations.

It is easy on these principles to explain the formation of elastic fluids, which takes place whenever bodies receive and absorb sufficient quantities of heat. All aeriform fluids owe their elastic property to the matter of heat; but the pressure of surrounding bodies, and more especially that of the air, is required to be removed or diminished before this state of extreme dilatation can take place, and if the weight of the atmosphere be entirely removed, as happens in the vacuum of the air pump, a body at a much lower temperature than would have been necessary to have produced the elastic state in the open air, may immediately become elastic. This accounts for the more rapid evaporation which takes place on lofty mountains, and hence we may perceive the necessity of mentioning in the account of experiments, at what degree of external pressure bodies have taken the form of elastic fluid, or at least the degree of pressure under which they can preserve it. For it must be observed, that all bodies capable of taking this state of elastic fluidity are not equally disposed to preserve it, and that in
this

this respect the differences between them are so great, that they have been distinguished into permanent and non-permanent. The former remain elastic during a very long space of time, and till some combination takes from them the matter of heat necessary to maintain their state; the second, which are denoted by the name of vapour, lose the elastic fluidity by a degree of pressure or refrigeration easy to be determined, and give out to all the surrounding bodies the matter of heat, which maintains their aeriform state: such are water, spirits of wine, ether, acetous acid, &c.

After these details it must be observed, first, that every elastic fluid is compounded of a base more or less solid, and the matter of heat. Secondly, that each of these bases require more or less heat to reduce them into the state of vapour or elastic fluid; and that it is doubtless in consequence of these properties that all elastic fluids differ from each other in their specific gravity, elasticity, &c.

Mr. Lavoisier has explained this theory in a very perspicuous manner, in a memoir printed among those of the academy in 1777.

Though we have divided elastic fluids into permanent and non-permanent, it must be observed, that this distinction does not really exist in nature, that it relates only to the heat and degree of pressure which are experienced

experienced in our climates, and in most of the habitable parts of the globe; and that if the cold and pressure were more considerable, those fluids, which are now taken to be the most permanent, would soon cease to be so; and in the same manner, for the contrary reason, ether and spirit of wine would become permanently elastic fluids at a certain height in the atmosphere, or at the high temperatures of certain climates, situate beneath the equator, &c.

The matter of heat, which contributes to the formation of permanently elastic fluids, is intimately combined with them, or latent, and does not become sensible, till these bodies lose this fluidity by combining with other substances. This phenomenon is a consequence of the general law we have established, that all bodies when they become more dense, suffer their heat to escape. Whenever an aeriform fluid or gas combines in such a manner as to become liquid or solid, it loses a great quantity of the matter of heat it before contained, and in order that it may pass to this state of density, it is necessary to present a body which has a greater affinity with its base than that base has with heat. Such in general is the cause of the fixation of elastic fluids; it may be further observed, that each of these fluids loses or suffers the disengagement of different quantities of heat, accordingly as it becomes more or less solid

solid in its new combination, or accordingly as that combination is capable of retaining more or less specific heat. This observation serves to explain the difference between the several kinds of combination, which are more or less rapid, accompanied with greater or less heat, and leave residues of various degrees of solidity, according to circumstances.

Lastly, If pressure and cold be the two means of condensing all elastic fluids, we may, perhaps, by employing strong degrees of both, succeed in causing them to lose their gaseous state, and obtain the bases separate and pure, by excluding the matter of heat which kept them in solution. By this means we should become acquainted with the bases of vital air, of mephitic, of inflammable air, &c. This has already been done with success in one instance by Mr. Monge, who has reduced the sulphureous gas to a state of liquidity by the application of a great degree of cold.

§ 2. Concerning the methodical Division or Classification of permanently Elastic Fluids.

The permanently elastic fluids are so numerous, as to render it necessary to class them methodically, or to dispose them in such order as may shew their respective similarity or differences.

I divide

I divide these fluids into four classes. In the first, I place those which are capable of maintaining combustion and respiration; in the second, those which cannot maintain either of these processes, and are not of a saline nature; the third contains the saline gases; and the fourth the inflammable gases. All the elastic fluids hitherto known, are arranged in the following tables, according to this method of disposition.

1st C L A S S.

Elastic fluids capable of maintaining combustion and respiration.

Species I. Vital air.

II. Atmospheric air.

2d C L A S S.

Elastic fluids which are incapable of maintaining combustion or respiration, and are not of a saline nature.

Species III. Mephitic.

IV. Nitrous air.

V. Aerated marine gas, or dephlogisticated marine acid gas.

3d C L A S S.

Elastic fluids which are incapable of maintaining combustion or respiration, and which are of a saline nature.

Species

Species VI. Cretaceous acid gas or fixed air.

VII. Sulphureous acid gas.

VIII. Fluor acid gas, or sparry acid.

IX. Muriatic acid gas.

X. Alkaline gas.

4th C L A S S.

Elastic fluids incapable of maintaining combustion or respiration, and which are inflammable.

Species XI. Aqueous inflammable gas, or pure inflammable gas.

XII. Hepatic gas.

XIII. Phosphoric gas.

XIV. Mephitized inflammable gas.

XV. Cretaceous inflammable gas.

XVI. Carbonaceous inflammable gas.

§ 3. Concerning the Nature and principal Characters of the several Kinds of Elastic * Fluids.

1. Vital air, called by its discoverer, Dr. Priestley, dephlogisticated air, and by some other English writers empyreal air, or

* Part of the following consists of repetitions of some part of the work itself, but it seemed desirable to bring them together in one point of view, and to connect them with facts discovered since the printing of the work. These newly discovered facts are more particularly enlarged on in the present discourse.

the

the principium forbile, is now obtained from a variety of substances. Precipitate per se or calx of mercury, red precipitate or mercury calcined by the nitrous acid, the precipitates of different mercurial salts by caustic alkalis, minium moistened with nitrous acid, nitres with alkaline or earthy bases, lunar nitre, manganese, either alone or moistened with vitriolic acid, the dephlogisticated marine acid of Scheele, or aerated marine acid of the French chemists, acetated mercury, arsenicated zink afford this fluid in various quantities by the action of light and heat, its disengagement being manifestly owing to this last agent. It does not exist entire in all these bodies, as in fact they contain nothing more than its solid base, which is melted by the heat, and put into the state of elastic fluidity; the metallic calces being revived in proportion as this fluid is disengaged. Vital air is likewise obtained from the leaves of plants immersed in water impregnated with the cretaceous acid, and exposed to the contact of the sun's rays.

Vital air is often mixed with a small quantity of mephitic. This fluid, when obtained from precipitate per se or manganese, and by means of the leaves of plants, does not contain mephitic air.

Vital air is rather heavier than the air of the atmosphere. It is the only elastic fluid capable of maintaining combustion, and is
three

three times as effectual as atmospheric air in this process. That is to say, a body which requires four cubic feet of atmospheric air to be completely burned, will require no more than one cubic foot of vital air for the same purpose. Combustion in this last fluid is made with an excessive heat and light: these two phenomena arise from the rapid separation of fire, which quits the base of this air, in proportion as the base itself becomes fixed in the bodies which are burned. There are instances of combustions effected by this air, wherein heat only, and not light, is disengaged. This takes place when the disengagement is made slowly and successively, so that the matter of fire does not move with great rapidity. Vital air is equally effectual in the process of respiration; but as a great quantity of heat is disengaged, it should seem that this high degree of purity would be productive of noxious effects in the animals which respire it, by rarefying the blood too much, and augmenting the rapidity of its circulation.

The base of vital air, combined with charcoal, with sulphur, with phosphorus, with mephitis, with a particular oil, with arsenic, &c. constitutes the cretaceous or carbonaceous, the vitriolic, the phosphoric, the nitrous, the saccharine, and the arsenical acids. From this property it is that Mr. Lavoisier calls its base the oxygenous principle;

principle ; and Mr. De Morveau, the acidifying principle. It must be observed, first, that these combinations do not always take place when the combustible bodies are plunged cold into vital air, and that it is necessary at least for their rapid production, that the temperature be more or less elevated ; secondly, that this base, or oxygenous principle, enters in different proportions into the compounds, in order to produce a complete saturation ; and that the compounds are different according to the quantities of the component parts ; thirdly, that its affinity for these different substances is not the same in all, so that phosphorus takes the oxygenous principle from the arsenic acid, and charcoal takes it from the phosphoric acid, &c. Fourthly, that when this principle passes from one of the bodies, in which it was fixed and unelastic, into another, a kind of slow combustion takes place, which is not attended with light, because the oxygenous principle is in the state of privation of the greatest part of its fire.

The base of vital air, or the oxygenous principle, united to the base of inflammable gas, constitutes water, and compounded with metals forms metallic calces ; charcoal decomposes water and metallic calces, because it has a greater affinity with the oxygenous principle, than the latter has with inflammable gas and metals.

Vital

Vital air discolours vegetable and animal substances; when absorbed by fat oils, it thickens them, and causes them to approach the state of wax; in combination with the muriatic acid, and the acid of vinegar, it forms the aerated or dephlogisticated muriatic acid and radical vinegar.

The strong light of the sun has the property of disengaging the oxygenous principle in the form of vital air, from many of its combinations, as the calces of mercury, the nitrous acid, &c.

II. Atmospheric air, or common air, is a compound of the vital air before described, and mephitic; 100 parts of this air contains 72 parts of mephitic, and 28 parts of vital air. Hence it will easily be understood, why no more than one fourth of a given quantity of vital air is absorbed during combustion; and likewise why the phenomena of combustion is effected in this atmospheric air more slowly, and with the disengagement of a less quantity of heat and light than in vital air. But it must be likewise observed, that there is not perhaps any kind of combustion in which the 28 parts of vital air are entirely absorbed and fixed in the combustible body: and that the aeriform residue of the atmospheric air, which has served the purpose of combustion, never consists of pure mephitic; even in such cases as the body

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burned remains in a fixed and solid state, and does not all mix with the elastic fluid, and much less is the mephitic residue in a state of purity, when the bodies burned under vessels filled with atmospheric air give out a residue in the permanent aeriform state, as charcoal, and all the organic matters which contain that substance, do. A great number of bodies alter the atmospheric air, and absorb vital air. We are not yet acquainted with any bodies which have the property of renewing and purifying the air of the atmosphere, except the leaves of vegetables, which pour out vital air disengaged from the cretaceous acid and water, by the decomposition effected in consequence of the action of the sun's light.

III. The mephitic, which exists in great quantities in the atmosphere, is distinguished by this peculiar name by Mr. Lavoisier, because it very quickly destroys animal life, and extinguishes combustion; and likewise, because this name has not yet been used, except very generally, without being applied to any substance in particular. It is the same elastic fluid which Dr. Priestley called phlogisticated air, because he thought that it was nothing but air altered by phlogiston, disengaged from bodies in combustion, or from odoriferous bodies; or in short, by all the operations of nature and art, which he calls phlogisticating processes.

But

But it is now ascertained, that this fluid exists ready formed in the atmosphere, and is developed in proportion as the vital air is absorbed. Modern philosophers have made the most important discoveries respecting this elastic fluid: there are several means of procuring it in a state of purity, but the process usually employed consists in that of exposing liver of sulphur in the liquid state to a given quantity of atmospheric air under a glass vessel. The liver absorbs the vital air by degrees, and when the absorption is complete, the pure mephitic remains. Mr. Scheele is the inventor of this process. Mephitic air is likewise obtained, according to the discovery of Mr. Berthollet, by treating muscular flesh, or the fibrous part of the blood well washed in an apparatus proper to receive the aeriform fluid which is produced: but it is necessary that these animal matters should be very fresh; for if they are at all altered by putrefaction, they emit the cretaceous acid mixed with mephitic. I have discovered that the bladders of carp, in which Dr. Priestley had before observed noxious air, are full of this kind of fluid, and that it is easily collected by breaking them underneath glass vessels filled with water.

Mephitic is heavier than atmospheric air. It instantly extinguishes a lighted taper, and very quickly deprives animals of life, when

plunged in it. Mixed with vital air in the proportion of 72 to 28, it forms artificial atmospheric air. If it be added to the vital air in a greater proportion, it constitutes an elastic fluid noxious to animals. Neither water, earths, nor acids, have any sensible action on this air. Yet it seems capable of being absorbed by the nitrous acid, which it renders fuming. Mr. Cavendish has discovered that 3 parts of mephitic mixed with 7 parts of vital air, and exposed to the passage of the electric spark, is gradually condensed, and produces the nitrous acid: an experiment which clearly exhibits the theory of the formation of this acid in the atmosphere. Mr. Berthollet, in decomposing the volatile alkali, either by the nitrous acid, or by the aerated muriatic acid, or in the detonation of fulminating gold, has found that the alkali consists of 5 parts of mephitic, and one of inflammable air. He has likewise discovered that animal matters contain much mephitic, and that it is the combination of this mephitic with the inflammable gas, which forms the volatile alkali obtained by the action of fire, and by putrefaction; that the plants which afford this same salt by distillation, owe its formation to the mephitic they contain; and that they are justly entitled to the name of animal plants, which some chemists have given them. I have since ascertained,

certained, first, that of all animal matters the fibrous part is that which furnishes the greatest quantity of mephitic, by the application of the nitrous acid; second, that after putrefaction the mephitic is no longer attainable, but that a great quantity of volatile alkali is produced.

These very remarkable properties of mephitic are more particularly entitled to the attention of physicians; they throw great light on the difference between vegetable and animal matters, on the formation of volatile alkali, on putrefaction, and on the cause of the production of the nitrous acid by putrid animal matters.

As this elastic fluid has been confounded by certain writers with the cretaceous acid, it must be recollected that the mephitic has neither smell nor taste in any sensible degree, that it is not so heavy as this aeriform acid, that it does not redden the tincture of turnsole, nor precipitate the lime from lime-water.

IV. Nitrous gas was known to Hales; but Dr. Priestley was the first philosopher who paid a proper attention to its distinctive characters. This elastic fluid is disengaged during the action of a great number of combustible bodies on the nitrous acid; more especially metals, oils, mucilages, and spirit of wine: it extinguishes flame, deprives animals of life, is neither acid nor

alkaline, and is not altered by pure water; with pure air it forms again the nitrous acid, because it is itself nothing else but the nitrous acid deprived of a part of the oxygenous principle, and consequently composed of mephitic and the oxygenous principle, but containing more of the former, and less of the latter than the nitrous acid itself. Hence arises the difference between the several specimens of this gas, according to the proportions of mephitic and pure air which it contains; and hence the uncertainty which eudiometric experiments are liable to. It will be easily understood from these circumstances, why in many cases, and especially when a body very greedy of the oxygenous principle is employed to obtain nitrous gas, and which absorbs much of that principle for its saturation, a nitrous gas is obtained, containing mephitic disengaged, and sometimes the product is nothing else but mephitic. Lastly, it is to the same property of nitrous gas, that the singular effect of liver of sulphur on this gas is to be attributed. A solution of the liver, placed under a glass vessel full of nitrous gas, quickly absorbs a part; the remainder no longer becomes red by the contact of atmospheric air, but maintains combustion better than the air of the atmosphere: it is in fact air, somewhat more pure than common air; the proportion of vital air to mephitic is more considerable;

ble; but if the hepar be suffered to continue its action on the gas, all the vital air is readily absorbed, and the residue is pure mephitic. We must likewise observe, that nitrous gas produces a green colour in flame, before it extinguishes it; and that in a great number of instances this colour is produced by such aerial compounds as contain the mephitic.

These leading properties of nitrous gas, and in particular its rapid combination with pure air, indicate its analogy with combustible bodies; and Macquer has remarked, that the artificial fixation of the nitrous acid, which takes place in the mixture of these two gases, is a kind of combustion. But as this appearance is not accompanied with flame, I have not judged it proper to rank the nitrous gas among the inflammable gases.

V. The aerated muriatic gas, or dephlogisticated muriatic gas of Scheele, is obtained with great facility during the mutual action of the native calx of manganese, and the muriatic acid: it is known that this production of a peculiar gas is due to the transference of the base of pure air, or the oxygenous principle of the calx of manganese into the muriatic acid. This gas always has a yellow greenish colour, with a strong and penetrating smell; it is not acid, extinguishes flame, and quickly destroys animal life;

life; discolours dyed stuffs, the tincture of turnsole, syrup of violets, and vegetables, by reducing them to a white. It discolours, and even blanches yellow wax, &c. It decomposes the volatile alkali, which may therefore be used as a preservative against its noxious effects; it separates the mephitic, in proportion as the oxygenous principle of the muriatic gas unites with the inflammable gas of the volatile alkali, with which it forms water. It thickens fat oils, calcines metals, not excepting mercury and gold, and dissolves in water, to which it communicates all these properties. The contact of light gradually decomposes it, and reduces it to the state of pure muriatic acid.

The formation of the aerated muriatic acid, and its gas, is one of the most singular discoveries of modern chemistry; this discovery shews that the habitude of the muriatic acid with combustible bodies is absolutely contrary to that of the other acids: all these salts appear, in fact, to be decomposed by many metals, which have in general a stronger attraction for the oxygenous principle, than exists between this last and the combustible bases of the acids. The muriatic acid, on the contrary, is not decomposed by metals, which cannot deprive it of its oxygenous principle; and in consequence of this property, it does not appear to act on the greater part of them; its base, nearly discovered,

discovered, not only attracts the acidifying principle with great force, but is even capable of taking it from many metallic calces, as has been instanced in the calx of manganese. An excess of the oxygenous principle takes away its acidity, which is contrary to what happens with many other combustible bodies.* This excess renders it capable of acting on such metals, as in its ordinary state it does not affect; such in particular are the regulus of antimony, mercury, silver, and gold. In proportion as these metals deprive it of the excess of the oxygenous principle, they become calcined, and are dissolved in the muriatic acid, which recovers, at the same time, its first state. These calcinations and metallic solutions, by the aerated muriatic acid, are made without effervescence, like the solution of a salt in water; because the metal gradually takes away the superabundant oxygenous principle from the liquid, without being necessitated to disengage the combustible base. These properties of the muriatic acid, and more especially the reduction of the metallic calces, seem to point out that it contains some principle of an oily nature.

* It must be remarked in this place, that the name of oxygenous principle does not seem in all cases to agree with the base of air, since its combination does not always form acids; and since it even deprives the muriatic acid of its acidity. T.

VI. The cretaceous acid gas, originally called fixed air by Dr. Black, who first discovered it in chalk and alkali, requires the most attentive consideration. We shall confine ourselves at present to the enumeration of the effect which the discovery of the properties of this elastic fluid has had on the whole of chemical science. First, it has added one to the number of acids. Secondly, it has shewn the cause of the effervescence which mild alkalies, chalk, calcareous spar, and magnesia, produce with stronger acids than itself. Thirdly, it has caused a distinction to be made of all alkaline matters into two states, the state of purity or causticity, and the mild state, having the property of effervescence. Fourthly, it has greatly enlightened the history of the elective attractions of acids for volatile alkali and lime. Fifthly, it exhibits the first instance of an acid, which prefers lime to fixed alkalies. Sixthly, the history of mephitic caverns, in which animals cannot live, is become very clear and simple, in consequence of this discovery. Seventhly, the analysis of waters has been rendered more perfect from the accurate knowledge of such as are called gaseous, spiritous, acidulous, and in consequence of that knowledge we have succeeded in perfectly imitating them. Eighthly, it has thrown great light on the solution of iron in many waters, and on the means of procuring

curing martial waters entirely similar to those in nature. Ninthly, It has exhibited a class of neutral, earthy, alkaline, and metallic salts, in which the cretaceous acid is a principal part; and which are distinguished in this work by the name of chalks. Lastly, it has opened a new field to the researches of chemists and natural philosophers, and has given new ardour to those who made these discoveries. The name of Black will be ever memorable in the annals of chemistry, and will endure as long as the science itself.

The formation of the cretaceous acid by the union of charcoal and the base of pure air, as asserted by Mr. Lavoisier, is at present admitted by many French chemists. This theory explains all the phenomena relative to the production of this elastic fluid, since it is known that plumbago consists of charcoal united to a small portion of iron. That some metals, particularly iron, contain in many cases plumbago already formed.*

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* Messrs. Vandermonde, Monge, and Berthollet, have made a series of experiments concerning the principal states in which iron exists, and have determined that their difference depends on the quantity of plumbago, and of the oxygenous principle they contain. They consider, 1. cast iron as iron, a part of which still retains the oxygenous principle, and is combined with various doses of plumbago. 2. Forged iron as the purest of all, or the nearest to the perfect metallic state, containing the smallest possible quantity of plumbago;

As to the production of this acid by the electric spark in vital air, it must be observed, that in the experiments of Mr. Landriani, the iron, which served as a conductor to the electric fluid, is the cause of this phenomenon by virtue of the plumbago it contained, and the small quantity of acid produced is an additional proof that this explication is well founded. There are, doubtless, many cases, in which the cretaceous acid is decomposed and resolved into its principles like the other acids. Thus it is, for example, that water, charged with this acid, is much better adapted for the production of vital air by means of leaves exposed to the rays of the sun; because the vegetable organization absorbs the carbonaceous principle, while the light, acting like heat, contributes to the separation of the oxygenous principle in the form of vital air. It is still more remarkable, that certain calces of iron, distilled in the pneumatic apparatus, afford only the cretaceous acid in passing to the state of *Æthiops* or black calx of iron. This

plumbago; from which, however, this metal is never totally deprived. 3. Steel as a compound of iron, perfectly reduced with more or less plumbago. Note of the author.

The author ought not to have omitted mentioning Bergman, by whose experiments, given in his invaluable *Traité de Analyse ferri*, the foregoing facts were originally ascertained; more especially as the ingenious chemists here cited do not appear either from necessity or inclination disposed to conceal the claims of that great philosopher. T.

depends

depends on the coal or the plumbago which many species of iron contain. This principle takes up a portion of the oxygenous principle, and both form the cretaceous acid.

VII. The sulphureous acid gas, named vitriolic acid air, by Dr. Priestley, is formed whenever a combustible body takes away a part of the oxygenous principle, which is united to sulphur in the vitriolic acid. It seems, therefore, to be nothing but sulphur united to a quantity of the oxygenous principle less than that with which it constitutes vitriolic acid; it is a kind of middle substance between this last and sulphur; it is likewise formed when sulphur burning slowly absorbs but a small quantity of the base of the pure air contained in the atmosphere.

The sulphureous gas is very soluble in water; it destroys many vegetable colours; and in this character it resembles the aerated muriatic acid. So that its oxygenous principle seems to be either totally or nearly disengaged. When united with alkaline bases, the sulphureous acid gas forms neutral salts different from those which are formed by the vitriolic acid, both in their figure, their taste, and more especially in the property of being decomposed by the more feeble acids, not excepting even that of vinegar. The sulphureous neutral salts gradually absorb the oxygenous principle of the atmosphere, and do

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do not then differ from salts formed by the vitriolic acid itself.

As the metals which reduce the vitriolic acid into the state of sulphureous acid gas do not effect this, but by the assistance of a certain degree of heat, it appears that this decomposition is the consequence of a double attraction. In fact, while the metal tends to absorb the oxygenous principle of the vitriolic acid, and becomes calcined, the heat combines with the sulphur and a portion of the oxygenous principle, and thus produces the sulphureous gas. But this gas is one of those which has been fixed or condensed into the liquid state by mere refrigeration; and from this circumstance we may form a general conclusion respecting the permanency of the elasticity of these fluids.

VIII. The fluor, or sparry acid gas of Dr. Priestley, is obtained from fluor or vitreous spar by means of the vitriolic acid. The characteristic property of the sparry acid, is to dissolve and volatilize in its elastic state, the quartzose earth which it seizes from glass vessels. With alkaline bases it forms salts, totally different from those of the other acids; and it has not yet been determined that it is a modification either of the vitriolic, or of the muriatic acids; though several chemists have maintained this opinion. Its principles are not known, more particularly its base; but the presence of the oxygenous

nous principle is admitted in this as well as in all the other acids.

IX. The muriatic acid gas of Dr. Priestley is easily obtained, by heating spirit of salt, or liquid muriatic acid in a retort, whose neck is plunged beneath a vessel filled with mercury. It may likewise be obtained in the same apparatus, by heating a mixture of common salt and oil of vitriol. This elastic fluid has a strong and penetrating smell. It extinguishes candles, destroys the life of animals, reddens blue vegetable colours, absorbs the vapours of water which float in the air, and forms with them a white fume. In liquid water it becomes dissolved, and loses that heat which maintained its elastic state. It causes ice to melt with great rapidity, by reason of the heat it gives out the instant of its combination with water. It is absorbed by charcoal and by sponge; unites with all the alkaline bases, and forms muriatic salts; and dissolves camphor. The nature of this air is not yet well known; neither has any one yet succeeded in separating the oxygenous principle from its base. It does not act on metals, which consequently are incapable of decomposing it, as they do the other acids. These properties shew, that the liquid muriatic acid, or spirit of salt, is nothing more than an acid fixed in the water, of whose liquidity it participates. It has not yet been accurately determined at what degree

degree of heat and pressure it acquires, and preserves the state of elastic fluidity. These facts, together with those which constitute the history of the aerated muriatic gas, tend greatly to explain the solution of metals by this acid, and its small degree of action on oils, spirit of wine, &c.

X. The alkaline gas, discovered by Dr. Priestley, is disengaged by heat from the volatile fluor alkali, and still more readily from the mixture of common sal-ammoniac with quick lime. This fluid collected in glass vessels over mercury, is somewhat heavier than atmospheric air; it has not been determined at what degree of cold or pressure it loses its aeriform fluidity. It unites with water, giving out at the same time much heat. It melts ice, converts the syrop of violets, and blue and red flowers to a green; and combines rapidly with the acid gases of chalk, sulphur, and common salt. These combinations are attended with much heat, which immediately abandons the two elastic fluids at the instant that they become solid.

Alkaline gas is rapidly decomposed by the contact of aerated muriatic gas, the decomposition being attended with heat. Water charged with the muriatic acid is formed, and the aeriform mephitic remains. This experiment, as well as many others already cited, shews, that the volatile alkali is composed of inflammable gas and mephitic. The decom-

decomposition of ammoniacal copper of fulminating gold, which produce water by means of the action of fire; the reduction of the metal, and the mephitic obtained, still further prove that the volatile alkali is composed of the principles here mentioned. In fact, the inflammable gas contained in the alkali, having more affinity with the oxygenous principle than the copper and the gold have, takes it from the calces of these metals, and forms water, leaving, at the same time, the mephitic in a state of liberty. The calces of zink and of iron, which decompose water in their metallic state, do not decompose the volatile alkali in the same manner; because these metals have a greater affinity with the oxygenous principle than the latter has with the inflammable gas.

XI. Pure, or aqueous inflammable gas, universally known by the improper name of inflammable air, is the lightest of all the aeriform fluids. When it is very pure, it is thirteen times lighter than atmospheric air; extinguishes fire; kills animals; takes fire* by the contact of the electric spark, or any combustible body already in a state of ignition; and burns with a brilliant flame. Fourteen parts of this gas in weight absorb eighty-six of vital air, during their complete combustion; and very pure water is formed,

* Provided vital air be present. T.

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provided these two fluids themselves be in a state of purity. All substances, which have a greater affinity with one of these two principles of water than they have with each other, decompose this liquid. Thus it is, that iron, zink, charcoal, and oils, decompose water, and separate the inflammable gas, because these bodies have more affinity with the base of the vital air, or the oxygenous principle, than this last has with the inflammable gas. Hence it is clear, that the inflammable gas cannot decompose the cretaceous acid, and the calces of zink and of iron. On the contrary, sulphur, and the metals which do not decompose water, give out the oxygenous principle they contain when in the state of vitriolic acid, or of metallic calces, to the inflammable air; by which means the first is reduced to the state of sulphur, and the second to the metallic state. It is this decomposition of water by iron and zink, which is the cause of the inflammable gas produced during the solution of these two metals in the vitriolic, muriatic, cretaceous, and acetous acids.

The leaves of vegetables, on the contrary, possess the property of absorbing the inflammable gas of water, and permitting the oxygenous principle to become disengaged in the state of pure air. Light contributes much to this decomposition, which does not take place without its contact; it seems to melt,

or give fluidity to the oxyginous principle, and causes it to become pure air. In proportion as this air is disengaged, the inflammable gas becomes fixed in the plant, and doubtless causes the production of oil. It is not yet known what substances inflammable air combines with in order to form oils.

Inflammable gas combined with mephitic, constitutes the volatile alkali, as we have already observed. This composition has been analytically demonstrated by Mr. Berthollet, but he has not yet succeeded in composing the volatile alkali by the direct union of these two bodies.

The matter of heat contained in inflammable gas has not yet been separated, except in such cases as this body enters into a compound state; the base of this aeriform fluid is therefore unknown. The pressure and the degree of cold necessary to effect this separation are not yet in our power; and every experiment serves to shew that both the one and the other must be in the extreme to produce this effect.

It is to the sudden disengagement and rapid inflammation of this gas, that all the fulminations and detonations observed in chemistry are to be attributed, and the instantaneous recombination of water is very often the result of these detonations.

Inflammable gas is greatly concerned in the phenomena of nature. It is produced

and disengaged in large quantities in mines. It reduces and colours many metallic calces. When elevated in the atmosphere, it is transported by the winds, and set on fire by electricity, where it consequently constitutes a part of the lightning; and in its detonation immediately forms water, which falls on the earth.

The inflammation of this gas by the electric spark is one of those most curious phenomena, whose cause is the least understood. The same difficulty occurs, when we consider the power of the electric spark to fix the mixture of pure air and mephitic in the form of nitrous acid.

XII. Hepatic gas has been well distinguished from the other inflammable gases by Bergman. It is obtained from livers of sulphur, or solid hepars, decomposed by means of acids in the pneumatic apparatus. This aeriform fluid has a very fetid odour. It kills animals, and turns the syrup of violets green. Vital air precipitates the sulphur. It takes fire by the electric spark, and by the contact of inflamed bodies, burning with a reddish blue flame, sulphur being at the same time deposited on the sides of the vessels. The smoking nitrous acid, and the sulphureous acid decompose, or destroy its elastic fluidity, and separate the sulphur. This gas unites with water; but the solution is decomposed
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by exposure to the air, and by the same acids as decompose the gas itself. Hepatic gas gives a deeper colour to the calces of lead and bismuth, and even reduces them. It precipitates muriatic solutions. Some metals, and in particular mercury and silver, separate the sulphur, so that it cannot be transferred in vessels over mercury without a great part of it being decomposed.

All these phenomena shew, that this gas contains sulphur in a state of extreme division. Mr. Gengembre, who has analyzed it, thinks it consists of pure or aqueous inflammable gas and sulphur. It is the dissolution or suspension of this last, that gives it its distinctive characters. The sulphur, notwithstanding its state of extreme division, does not burn at the same time as the inflammable gas, but is deposited in part during the combustion of the latter.

It is this gas which mineralizes the sulphureous or hepatic waters. The ordinary acids do not precipitate the sulphur; but the fuming nitrous acid, and the sulphureous acid, in which the oxygenous principle is not strongly adherent, separate the sulphur, while they absorb the inflammable air.

The knowledge of hepatic gas explains many difficulties relating to the nature of sulphur. First, we know why the solid hepar has scarcely any smell, and why it emits so strong a smell when it is moistened.

Secondly, it appears that water, which sulphur alone is incapable of decomposing, is easily separated into its principles, by the double action of sulphur and alkaline matters. Thirdly, the decomposition of livers of sulphur by exposure to air, and by many metallic calces, which are incapable of decomposing water, is easily understood. Fourthly, the theory of the formation of sulphureous mineral waters may be readily explained, as well as the history of their decomposition.

XIII. Phosphoric gas was discovered by Mr. Gengembre; he obtained it by boiling a solution of caustic vegetable alkali with half its weight of phosphorus, and receiving the elastic fluid, which is disengaged under glass vessels filled with mercury. This gas is very fetid, destroys animal life, takes fire spontaneously by the contact of air; and with a slight explosion. The solid phosphoric acid, which it affords by burning, forms a kind of crown in a still air, which increases in diameter as it rises. When vital air is mixed with this air under glass vessels, it burns with great rapidity, producing so considerable a quantity of heat, and consequently dilatation, that the glasses are shattered to pieces, unless they be very thick. Mr. Gengembre considers this new gas as a solution of phosphorus in inflammable gas;

gas ; it greatly resembles hepatic gas, from which it differs only in the nature of the combustible body suspended in the inflammable gas. As phosphorus is much more combustible than sulphur, the phosphoric gas takes fire in the air. The phosphorus, when inflamed, communicates its combustion to the inflammable gas. In the hepatic gas, on the contrary, the inflammable gas does not take fire, but by the contact of some body in ignition ; and the sulphur, for want of a sufficient heat, separates without burning.

XIV. I give the name of mephitized inflammable gas to the aeriform fluid which consists of aqueous, or pure inflammable gas, and mephitis. This gas is the same as that which was called inflammable air of marshes, by Mr. Volta. It is produced by the putrefaction of certain vegetable matters, and of almost all animal substances. It is disengaged from standing waters, and in all places where animal matters putrify in water. It accompanies, precedes, or follows the formation of the volatile alkali, which takes place in putrefaction. I suspect it to be a simple mixture without the chemical composition ; because volatile alkali would be formed, if the combination were perfect. It differs from volatile alkali, first, in the elastic state of the two fluids, which constitute it ; secondly, in the proportion of these

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elastic

elastic fluids, which varies in this mixed gas, while the quantity of the combined bases is always the same in volatile alkali. It is to Mr. Berthollet that we are indebted for the exact knowledge we possess of the properties of this gas. In the years 1778 and 1779, I examined the inflammable gas of marshes, and observed that it contained the cretaceous acid; but in many of these gases, collected in different places near Paris, I found a mixture, which I did not accurately distinguish; though I observed in my collection of Memoirs, in octavo, page 164, that it is sometimes accompanied, and even succeeded, by the phlogisticated gas; which, as I have elsewhere observed, is now called mephitis. Mr. Berthollet has given to these assertions, which were unsettled at the time that I inserted them in my Memoirs, a degree of certainty and precision, which has induced me to distinguish these gases by the name here made use of.

Mephitized gas burns with a blue flame; it does not detonate with vital air, without difficulty. After detonation in the eudiometer of Mr. Volta, some drops of water are found, and a residue of mephitis more or less pure.

XV. I distinguish by the epithet of cretaceous inflammable gas, the mixture of pure inflammable gas and elastic cretaceous acid.

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It is obtained by distillation, from many vegetable matters, and in particular from tartar, and all the tartareous salts, or the acetous salts; from hard woods, or charcoal which is burned by the assistance of water, from pit coal, &c. It burns with difficulty; but the cretaceous acid may compose three-fourths of its volume without its ceasing to be combustible. This acid may be separated by means of lime-water, or caustic alkalis. It is a simple mixture, without combination. The inflammable air cannot, in fact, decompose the cretaceous acid, because the carbonaceous principle, or charcoal, decomposes the water, with whose oxygenous principle it has a greater affinity than this last has to the inflammable gas.

XVI. Lastly, it is now known, that charcoal, though very fixed in closed vessels, and in our ordinary fires, is capable of being reduced into vapours, by means of a very high temperature; and that it is likewise soluble in elastic fluids. Inflammable gas, more especially, has the property of dissolving this substance, and of holding it suspended; it is often, therefore, taken up by this fluid, at the time of its assuming the elastic form. It is this fixed gas which is disengaged, when cast iron or steel is dissolved in spirit of vitriol; the carbonaceous matter being absorbed by the first in the furnace, and by the

the second during the cementation. It is even found that charcoal may be immediately dissolved in this gas, by causing the united rays of the sun, by means of a mirror, to fall on a piece of that substance placed above the mercury, made use of to confine the inflammable air. This fluid burns with a blue flame, attended with small white or reddish sparkles. The charcoal dissolved in this gas modifies its effects, and alters the results of its combinations. Hence it is, that a mixed gas, formed by the solution of charcoal in mephitic, appears to be the colouring matter of Prussian blue, as Mr. Berthollet conjectures. We are not yet acquainted with all the compounds into which charcoal enters; and the same observation is likewise applicable to the various mixtures of all the gases with each other, which certainly take place in many combinations and decompositions, and have not yet been strictly attended to by chemists.

§ IV. The Application of such Facts, as are known respecting the Nature and Properties of elastic Fluids, to the great chemical Phenomena of Nature and Art.

It is now well known, that there is scarcely a single chemical phenomenon, in which a disengagement or fixation of some elastic fluid does not take place; and that both these events frequently happen at the same

same time. The discoveries of the modern chemists shew, therefore, that the ancient explications of these phenomena were not satisfactory; and the many difficulties, which these discoveries have removed, sufficiently shew their importance in the science of natural philosophy.

When we compare the numerous facts, which form the whole of our knowledge of chemistry together, we find that they may be reduced to certain general classes.

This arrangement is become so much the more necessary, as the connection and mutual illustration of these facts must hereafter constitute the true elements of chemical science; but this last object cannot be properly accomplished till all the general phenomena are explained; and as many of them yet remain in obscurity, this elementary method of treating the whole of chemistry, cannot, in the present state of our knowledge, be considered otherwise than as a project or scheme, whose importance and utility deserve the serious attention of natural philosophers. It is by way of assisting in the execution of this project; or at least with a hope of shewing the possibility of its execution, that I have thought proper to collect all the facts and chemical theory under sixteen principal heads, which comprehend the various changes produced in natural bodies by means of their chemical attraction. And that these phenomena may be explained methodically,

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thodically, by proceeding from simple effects to those that are more compound, I shall dispose them in the following manner :

1. The production, or disengagement of heat and its absorption, with the effects of the one and of the other.
2. The effects of air in combustion.
3. The effects of light upon bodies.
4. The formation of water, and its decomposition.
5. The production and decomposition of earths.
6. The formation and decomposition of alkalis.
7. The formation and decomposition of acids.
8. The combination of acids with earths and alkalies.
9. The peculiar combustion of diamond, of inflammable gas, of sulphur, and of plumbago.
10. The calcination and reduction of metals.
11. The dissolution of metals by salts, and the properties of neutral metallic salts.
12. The formation of the immediate principles of vegetables by vegetation.
13. The production, the differences, and the decomposition of vegetable acids.
14. The spirituous fermentation ; the com-

combustion, and combinations of ardent spirit.

15. The formation of animal matters.
16. The decomposition of animal matters and putrefaction.

We will briefly consider each of these phenomena, and shew their connection with the properties of elastic fluids.

I. The production of heat arises either from a strong pressure, which disengages it from bodies in which it was included, or from a combination by which it is set at liberty. It must be observed, that this phenomenon takes place more especially when an elastic fluid becomes fixed in a body; because the aeriform state supposes, as we have already explained, the presence of a great quantity of combined heat. It must likewise be observed, that various bodies containing different quantities, or having different capacities for heat; pressure, or combination, causes it to be extricated in very different doses. This phenomenon, therefore, which accompanies a great number of chemical operations, requires to be attended to and estimated with great exactness in all experimental inquiries.

The same observation holds with respect to the apparent destruction or absorption of heat, very frequently observed in chemical processes. It always depends on the augmentation of the magnitudes of bodies, by means of which
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their capacities for the matter of heat are increased. We may, therefore, conceive mechanically, or by the simple consideration of the change that takes place among the particles of bodies, what happens in both the phenomena.

II. Combustion is one of the most important phenomena in nature. There are two kinds or classes of combustion; namely, such as are made with access of common air, and such as apparently are made without the access of air; though, in fact, it is contained in the substances themselves.

Combustions effected by the contact of air, are, as we have already observed, combinations of the combustible body with the base of vital air, or the oxygenous principle. In proportion as these combinations take place, the matter of fire is separated from the oxygenous principle, and appears under the form of heat and light. There are combustible bodies which slowly disengage the fire of the air, and do not give out heat sufficiently strong to deserve the name of combustion. Others, on the contrary, cause the fire to be disengaged rapidly, under the form of light; and at the same time giving a greater or less degree of oscillation to this light, they cause different shades of colour, if the theory of Euler respecting the luminous rays of different colours be admitted, which asserts, that they consist of the

the same matter vibrating differently. In certain combinations, effected in the open air, the combustible bodies have so strong a degree of attraction to the base of this elastic fluid, that they very readily seize it. Others, in order that they may combine with the oxygenous principle, require a very high temperature, which seems to favour the attraction of combustible bodies for this base. This theory explains how bodies become heavier by being burned, and the cause of impurity of the atmospheric air after combustion; for the proportion of mephitic then becomes much greater. And the diversity of phenomena, such as flame, heat, and rarefaction, which accompany every kind of combustion made in the air, are by this theory explained with equal facility.

The second kind of combustion is very often performed in closed vessels. It consists, in general, in the transition of the oxygenous principle from a body already burned, into another which has not been burned. It depends on the different elective attractions of the oxygenous principle for the several combustible bases. Such is the calcination of metals by acids; the reduction of metallic calces by charcoal; the combustion of sulphur, of phosphorus, of charcoal, and of plumbago, by the nitrous acid; the combustion of the bases of inflammable gas fixed as a principle in sal-ammoniac or volatile

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tile alkali, by the muriatic or aerated acid, &c. &c. In all these cases, the oxygenous principle passes from one body into another; and as it does not appear to be melted into an elastic fluid by the fire, these combustions are very often made without the appearance of flame. We may likewise add, that in these slow combustions, the combustible property is not lost, but is renewed in the body, which parts with its oxygenous principle, while it ceases to exist in the other body which has absorbed it.

III. The effects of light on bodies have not yet been estimated but by their results; the cause not having yet been well explained. The action of light upon vegetables has long been known; namely, that it colours them, and produces combustible bodies. Scheele observed, that the rays of the sun colours the nitrous acid, luna cornea, mercurial precipitates, &c.; and it is now acknowledged that all these effects are accompanied with the disengagement of a certain quantity of vital air. Light, therefore, acts in the same manner on these bodies as heat. It separates the oxygenous principle, which it melts, and causes to pass to the state of elastic fluidity. In this manner it is, that it contributes to the decomposition of the cretaceous acid by means of the leaves of vegetables, by a double affinity; first, that of light, with the oxygenous principle, which is disengaged in
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the form of vital air; and secondly, that of the vegetable matter, with the carbonaceous principle. It is by the same action, that light favours the decomposition of water by means of the organs of vegetables, and contributes to the formation of the oxygenous principle. By attending more carefully to the action of light on many natural bodies than has yet been done, there is no doubt but important discoveries will be made, as I observed in the year 1780.

IV. The formation of water, and its decomposition, depend entirely on the affinities of the oxygenous principle, which is one of its component parts. It has been for some time known, that zink, iron, oils, and charcoal, have the property of separating the component parts of water from each other, by absorbing the oxygenous principle, and disengaging the inflammable gas. The extreme tenuity or lightness of this gas is the cause why so high a temperature is necessary for immediately effecting of this decomposition. It seems that the base of this gas, which is usually either liquid or solid, in the two most common states of water at the surface of the globe, has a very great capacity for the matter of heat; and it even seems that this base, though combined with the oxygenous principle in the form of water, still possesses the property of absorbing much of that matter. It is by virtue of this property, that aqueous vapour is lighter than air. This happy discovery

covery of the nature of water, and its decomposition, throws great light on the theories of metallic solutions, of the calcination of many metals by the vapour of water, the formation of the immediate principles of vegetables, of ardent spirit, and the putrefactive fermentation. And it may also be observed, that the theory of almost every fact in chemistry depends on the affinities of the oxygenous principle. Hence, likewise, we are enabled to explain several of the atmospheric phenomena, as well as others relating to the formation of metals, and the laws followed by nature in the successive changes of organic matters, &c.

V. There are many important subjects of inquiry respecting of natural bodies, which are still desiderata among chemists. The formation of earths is one of these. Naturalists have entertained various opinions respecting the nature of earths. Many have thought that the transformation of flint into clay, was well proved; but these notions deserve to be considered in no other light than as ingenious hypotheses not yet proved by the facts. No chemist has yet converted siliceous earth into clay, nor clay into siliceous earth. Nature may, perhaps, produce this conversion; but art, which is not yet in possession of the means, can do nothing, till direct experiments have pointed them out. In the same manner ponderous earth, magnesia, and lime, have been considered

as compounds of the preceding earths, with certain other bodies; but these are suppositions not at all to be depended on. No chemist has yet directed his researches to this point, and the first data are still wanting.

VI. The formation of fixed alkalis is in the same state of uncertainty; and though such chemists as are well acquainted with modern discoveries, may perhaps suspect that the mephitic is a principle of these salts; it may even perhaps be admitted, that the base of this elastic fluid, which has been proved by Mr. Berthollet to exist in the volatile alkali, is the general principle of fixed alkalis, and alkaline earths; or in a word, the alkaliginous principle. It cannot, for example, be doubted but that fixed alkalis are partly decomposed in many chemical operations; they are manifestly changed into volatile alkali in the distillation of old soaps, and of the tartareous and acetous neutral salts. This conversion seems to shew, that fixed alkalis contain mephitic, which acting on the inflammable gas of the oil, forms volatile alkali. But the facts have not yet been examined with sufficient care, as to the quantities of the fixed alkali which appear to be decomposed, the volatile alkali they afford, and especially with regard to the residue, to admit of any strong dependence on this theory, though it must be allowed to possess no inconsiderable degree of probability.

VII. The formation of acids, and their decomposition, is one of the best known and most useful of the results of modern chemistry. It is known, that they are all formed of a base more or less combustible, united to the base of air; that this last being the same in all, is the cause of their acidity, and that their differences depend only on the substance combined with the oxygenous principle. It is known that the bases of the vitriolic, nitrous, cretaceous, arsenical, and phosphoric acids, are the substances called sulphur, mephitic, charcoal, arsenic, and phosphorus; but the bases of the muriatic, sparry, and boracic acids in the mineral kingdom, and most of those belonging to the vegetable kingdom, are still undiscovered.

This decomposition of acids is not difficult either to be conceived or explained. It takes place whenever a combustible body is presented to the acid, which has a stronger affinity with the base of air than this last has with the other principle of the acid: on this depends the theory of the formation of sulphureous and nitrous gases, &c.

VIII. The combination of acids with earths and alkalis constitutes the history of neutral salts, and of the affinities, or the elective attractions of these different matters for each other. It comprehends the examination of such phenomena as take place during

during their union; the taste they acquire, their form, solution, and crystallization; their alterations by fire, by air, and the mutual decompositions they undergo. This subject is treated of at large in the following work.

IX. The peculiar combustion of diamond is well known, as far as relates to the facts; but the compound produced by this combustion has not been examined. As to the combustion of the inflammable gas of sulphur, and of plumbago, it is referable to the history of water, and of the vitriolic and cretaceous acids. The carbonaceous inflammable air afforded by iron, zink, and perhaps many other metals during their solution in the vitriolic, muriatic, and acetous acids, and the cretaceous acid obtained by the detonation of the same matters with nitre, may be attributed to the plumbago contained in those metals.

X. The calcination and reduction of metals likewise constitute a part of the history of air and the oxygenous principle. The calcination of metals is now known to be a kind of combustion, consisting in the union and fixation of the base of air. Metallic calces being compounds of metals, and the oxygenous principle, the greater part of them cannot be reduced, but by the application of a body which has a stronger affinity with the latter, than this has with metallic substances. Charcoal, in this manner, absorb-

ing the oxygenous principle of metallic calces, forms with it the cretaceous or carbonaceous acid, which is disengaged in great quantities during their reduction. Certain metallic calces give out the oxygenous principle in the form of vital air, by the mere assistance of heat. These facts prove, that the oxygenous principle adheres to different metallic matters with various degrees of force; but two very important circumstances relative to the calcination of metals, and determined by the experiments of modern philosophers, are, first, that each metal absorbs a different quantity of the oxygenous principle, in order to its saturation. 2. That each of them may exist in very different states of calcination, or combined with different doses of the oxygenous principle, from the very commencement of calcination to its being perfectly finished.

An attentive examination of this second fact leads us to distinguish in each metallic calx several different states depending on the quantity of the oxygenous principle it contains. Thus we see that mercury, slightly calcined, is changed into a black powder in a variety of circumstances, which has been supposed to be the metal in a state of extreme division. In like manner, iron, in the form of *Æthiops martial*, is the first of its calces on account of the small quantity of the oxygenous principle it contains. Cold water readily

dily converts iron into this state. Lastly, copper, which is beginning to be calcined, or is united to the smallest possible quantity of the oxygenous principle, is brown or reddish white; while its perfect or saturated calx is of a deep green.

This distinction of metallic calces into different states of calcination, depending on the various quantities of the oxygenous principle contained in them, serves to explain a great number of phenomena, which were formerly attended with much difficulty.

XI. The solution of metals in different acids, the properties of these solutions, and the salts they furnish, agree likewise with the modern theory, and admit of a much clearer explanation than formerly. No solution can take place in an acid, unless the metal be first calcined.

Metals are calcined by the vitriolic acid, either by the acid itself, or by the water it is combined with. In the first case the acid is decomposed, and sulphureous gas is disengaged; in the second, the water is decomposed, and inflammable gas is disengaged. Some of the metals do not decompose the vitriolic acid, unless water be present; such are mercury, lead, &c. In the first case, the metals are not burned, unless the vitriolic acid be concentrated; in the second case, the metal has more power to decompose water, than to decompose the

vitriolic acid. Zink, iron, and other metals do not, therefore, readily become calcined, but by means of the diluted acid, because it is in fact the water which calcines them. The proof of this last fact is, that the vitriolic acid remains entire without decomposition. It is clear after this explanation, that a much greater quantity of the vitriolic acid will be required to dissolve a metal which decomposes the acid itself, than would be required to dissolve another metal, which decomposes water united to this acid: because in the former case, two different quantities of the acid are required; the first to calcine the metal, the second to dissolve the metallic calx: so that if no more were applied to the metal than the first mentioned quantity, nothing but a calx would be produced; and the second or additional quantity of vitriolic acid would be required to dissolve it. This is frequently done in our laboratories. Accurate observation has shewn, that metallic calces require a determinate proportion of the oxygenous principle, in order that they may be soluble in the vitriolic acid. When they are saturated with this principle they are not soluble, and long before saturation they are likewise insoluble. Thus we see, that when a vitriolic solution is too strongly heated, or has been long exposed to the air, in the first case the heat favours the action of the metallic calx on the

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the acid, so that it takes a greater quantity of the oxygenous principle than it had before; and consequently, it does not remain suspended in the acid: or, in the second case, it absorbs this same principle from the atmosphere, and when this exceeds the determinate quantity necessary for its remaining suspended, it falls of course. Hence the theory of vitriolic mother-waters. The metallic solutions in this acid do not afford crystals, but in the former case; and all these facts shew, that the metals themselves at first act on their solvents, and that the vitriolic acid does not attack them, till they have suffered a determinate degree of calcination.

The nitrous acid is likewise decomposed by the greater number of metals. These are calcined to a determinate degree by absorbing the oxygenous principle, with which they have a greater affinity than with the mephitis; but as they do not deprive the nitrous acid of the whole of its oxygenous principle, at least when the quantities of metal and of heat are not too great, the mephitis is separated, together with a portion of the oxygenous principle; and this peculiar combination forms nitrous gas. The nitrous is the most easily decomposed of all the acids. Its two principles adhere very weakly to each other; for which reason it has always been regarded as the principal solvent. Hence we see, likewise, why water
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is never decomposed during the reciprocal action of metals and the nitrous acid; and why this action is rendered nearly ineffectual by the addition of a great quantity of water. From this reason likewise it is, that metallic solutions, by means of the nitrous acid, never give out more than one species of elastic fluid, namely nitrous gas, mixed sometimes with a small quantity of mephitic; which happens more especially when the metals made use of have a very strong affinity with the oxygenous principle, and absorb it in great quantities.

Such metals, as are soluble in the nitrous acid, cannot remain united with it, unless the quantity of the oxygenous principle they are combined with be determinate, and not equal to absolute saturation. Many metals, as for example, bismuth, antimony, mercury, tin, and iron, are separated from the nitrous acid by mere standing, by heat, or by exposure to air; in which cases they continue to absorb the oxygenous principle of the solvent acid, or the surrounding atmosphere. The quantity of the nitrous acid must be very considerable: first, that the metal may be calcined; secondly, that the calx may be dissolved. If the first quantity only be added, the metal will remain in the form of calx, as happens with bismuth, zink, tin, and regulus of antimony.

The muriatic acid does not act on any metal,

metal, but by the assistance of water ; so that as there are but few metals which act upon water, there are likewise few which are immediately soluble in the muriatic acid ; and during their solution by this acid, inflammable air only is disengaged. These circumstances indicate, that the principles of the acid have a stronger adhesion to each other than those of every other acid ; and I am very much inclined to believe from this, that the unknown base of the muriatic acid has the strongest possible affinity with the oxygenous principle ; since none of those combustible bodies, which take it from the greater part of such bodies as contain it, can deprive this acid of that principle. But it dissolves metallic calces, when once formed, with great facility ; and even takes them from several other acids. It likewise dissolves them when saturated with the oxygenous principle, contrary to what happens with the other acids. These two last remarkable properties certainly depend on the tendency which the muriatic acid has to absorb an excess of the oxygenous principle ; a tendency, which is well demonstrated by the formation of the aerated muriatic acid and aqua regia. The action of all the other acids on metals is not yet sufficiently known, to enable us to speak of them with the same precision as we have done respecting the three foregoing. We shall therefore only observe,

observe, that metals ought not to decompose the cretaceous acid, because charcoal, which is one of the principles of this acid, has a stronger affinity with the oxygenous principle than this last has with metals; as the decomposition of metallic calces, by means of the carbonaceous principle, sufficiently proves.

Lastly, the precipitation of metallic calces, when united to acids, in the form of metals, by other metallic substances, is equally explicable by the various affinities of the oxygenous principle with these substances. When copper precipitates the calx of silver, and iron the calx of copper, in the metallic forms of silver and copper, the phenomena depend on the greater attraction of copper than of silver to the oxygenous principle, and of iron than of copper.

Inquiries into the formation of the immediate principles of vegetables are yet in their infancy. It has been long since observed, that plants grow very well in the purest water; and that by the assistance of water and atmospheric air, they obtain all their constituent principles. These, therefore, are the two materials from which they draw all their nourishment; or from which the mucilage, the oil, the coal, the acids, the colouring parts, &c. are produced. Since the time of the discoveries relating to gases, it has been observed, that they grow
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very quickly in air charged or mixed with the cretaceous acid, as well as in inflammable air. We have already observed, that leaves of plants decompose water and the cretaceous acid. They absorb the inflammable gas of the former, and the carbonaceous principle of the latter; disengaging pure air from the one as well as from the other: they therefore must absorb mephitic. These phenomena being properly attended to, tend greatly to explain the formation of charcoal, and of oil; for it cannot be doubted, but that this last principle is formed of inflammable gas fixed by some other substance, as it gives out much water during its combustion. But we are not yet acquainted with the formation of the colouring principle, of the various oils, of the spiritus rector, the fixed alkali, the glutinous parts, &c. We may, however, venture to foretell, that by making experiments on vegetation, as indicated by the new discoveries, we shall most probably arrive at the nature and constitution of all these immediate principles.

XII. No one has treated more fully and accurately on the history of vegetable acids than Mr. de Morveau, in his Dictionary of Chemistry, which makes a part of the Encyclopedia. He distinguishes vegetable acids into two classes, viz. such as exist ready formed in vegetables, and those of which they contain only the base, and which are produced
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by combining this base with the oxygenous principle obtained from different bodies, or existing in the vegetable itself, by means of the alteration its different principles are made to undergo. He observes, however, that this division is not perhaps very exact; because the formation of acids, by means of vegetation, resembles in strictness their formation by art; being effected by the combination of the acidifiable bases with the oxygenous principle in the internal parts of vegetables. Notwithstanding the force of this observation, the distinction proposed by this chemist is very useful; for the vegetable bases, which art converts into acids, scarcely ever become such in the processes of vegetation.

The first class may be divided into two orders, as Mr. de Morveau himself remarks. In the first may be arranged the vegetable acids ready formed, and in a state of purity, which may be extracted by simple pressure or infusion; as the acid of citrons, and the acid of galls. The second order may comprehend those which are partly neutralized, and are only to be separated by peculiar chemical operations. Such are the acids of benzoin, of tartar, of sorrel, and of apples.

The second class comprehends three orders of vegetable acids. 1. Those which are produced by the acetous fermentation. 2. Those which are obtained by the action of
of

of the nitrous acid; as for example, the saccharine acid. 3. Those obtained by distillation, and known by the names of empyreumatic acids; such are the acids obtained in this way from wood, from sugar, from tartar, &c. This division of vegetable acids proposed by Mr. de Morveau, is more exact than that of Mr. Weigel, which does not include the acids produced by the application of the nitrous acid.

We have examined the greater part of these acids in the third part of the present work; but the discoveries lately made, demand that we should in this place attend again to the general properties of all these salts, and some of them more particularly.

The vegetable acids ready formed, whether they be in a state of purity, or whether they be partly neutralized, are the products of a composition, effected by the vegetative powers, of an oily base with the oxygenous principle. They only possess the second rank among the immediate principles of vegetables, since the formation of oils has necessarily preceded their production. As oils differ among each other, vegetable acids must likewise have different properties; but they are all volatile, and decomposable by fire. Those whose bases exist only in vegetables, and are formed by the application of nitrous acid, as well as those which are developed by fermentation and distillation, owe their origin
to

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to the fixation of the oxygenous principle of the water, of the nitrous acid, or of the atmosphere in combination with oleaginous bases. It is easy to conceive, that if these bases be different, the several processes will be attended with different acid results.

However, though, on the one hand, the number of vegetable acids is considerably increased in consequence of late discoveries; yet the labours of many chemists, and in particular of Mr. Crell, seem to shew, that the acidifiable bases of many of these acids differ but slightly from each other, and may by various methods be made to afford absolutely the same salts, page 96, § 14. To complete my account of the vegetable kingdoms, I shall here explain the properties of the acids of wood, of camphor, of syrup, of benzoin, and of apples; and of the resemblance, which some time ago was observed between the bases of the acids of sugar and of sorrel, and likewise of those of tartar and of vinegar.

It has long been known, that wood affords an acid liquor by distillation. Goetling examined the acids of birch and box in the year 1779, and obtained with spirit of wine, together with these acids, a true æther. The acid requires to be rectified by a second distillation. Mr. de Morveau calls this the lignic acid, and denominates its neutral combinations lignites; as
for

for example, lignites of soda, of pot ash, &c.

Mr. Fontana suspects that this acid may be very different according to the wood from which it has been obtained; but birch, box, and beech, have been found to afford the same acid. Its combinations have not yet been much examined into. Mr. de Morveau, from the trials of Mr. Eloy Boursier de Clairveaux, affirms that calcareous and ponderous earths do not yield this acid to caustic fixed alkalis; that lime does not yield it to ponderous earth, nor magnesia to the pure volatile alkali.

Mr. Kosegart, by distilling colourless nitrous acid eight times successively from camphor, has changed that combustible body into a peculiar bitter acid, which crystallizes in the form of parallelipeds, and does not precipitate lime from other acids, as the saccharine acid does. This acid, denominated the camphoric acid by Mr. de Morveau, forms with the vegetable alkali, a salt in regular hexagons; with the mineral alkali, a salt in irregular crystals; with the volatile alkali, a salt likewise crystallizable; with magnesia, a pulverulent and soluble salt. It dissolves many metals. Mr. de Morveau gives the name of camphorites to its saline combinations. We must observe, that this acid is not yet sufficiently known to admit of our entering into any full account of it,

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or even to consider it as perfectly distinct from certain other acids.

The elder chemists, who distilled sugar and manna, observed that a penetrating acid was disengaged, to which they ascribed many singular properties. Lemery, Boerhaave, Hermann, and Cartheuser, began the examination of this acid; but Mr. Scrickel has been more particularly attentive to its characters. Mr. de Morveau calls this salt the syrupous acid, and distinguishes its combinations by the names of syrups. This celebrated chemist has observed, that the glass of the retort is attacked and corroded during the distillation of sugar. Mr. Scrickel rectifies this acid in earthen vessels, and concentrates it by congelation. It is contained ready formed in sugar, according to Mr. de Morveau, and by its superabundance in molasses, is the cause of the difficulty with which that salt is crystallized. This acid, in its concentrated state, is very penetrating; it quickly reddens the blue colours of vegetables; has a strong smell, and tinges the skin yellow, according to Cartheuser. In open vessels it is driven off by fire; and in closed vessels it is decomposed, leaving a carbonaceous residue. Its combinations with alkaline bases form salts different from those of the saccharine acid. It dissolves several metals. Mr. de Morveau disposes its elective attractions in the following order; vegetable alkali, mineral alkali, ponderous earth,

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earth, lime, magnesia, volatile alkali, clay, metallic calces, water, spirit of wine. We may likewise add, that this acid is obtained from honey, gums, farina, sugar of milk, and all mucilaginous and saccharine matters by distillation. It seems to me to be formed by the action of fire, and by the decomposition of water by oil.

The acid of benzoin, which has already been mentioned under the name of flowers of benzoin, has been examined by Scheele, and by Lichtenstein. The first obtained it by lixivation, with lime water, evaporation, and precipitation, by means of the muriatic acid. It is purified by solution in warm water, and crystallization. It is soluble in 24 parts of boiling water. The vitriolic and nitrous acids dissolve it, and it is easily separated again from these acids by the addition of cold water. It unites with effervescence to mild alkalies, from which it disengages the aerial acid, and forms with them peculiar salts, which Mr. de Morveau calls benzones. This acid contains an attenuated oil, which renders it volatile and combustible. It melts and is dissipated, when exposed in a spoon to the flame of a blow pipe. And it becomes hard with crystalline ramifications on its surface, if it be permitted to cool again after melting. Being kept twenty years in a half closed vessel, in a dry place, no part of it appeared to have been lost. It does not sensibly red-

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den the syrup of violets, but it acts strongly on the tincture of turnsole. Its taste is irritating, without any very sensible degree of acidity. Weak nitrous acid being distilled from the acid of benzoin, the latter was entirely volatilized without alteration; but a concentrated nitrous acid being employed, the acid of benzoin became fluid, more fixed, and according to Mr. Hermstadt, assumed the characters of the tartareous or saccharine acids. This last fact however, as Mr. de Morveau observes, wants confirmation. Mr. Scheele has discovered a combination of the acid of benzoin with volatile alkali, in the extract of urine, and the acid itself in the sugar of milk.

The malufian acid was thus named by Mr. de Morveau, because, though many other substances contain it as well as acids, it is most easily, and in the greatest purity, obtained from apples. To procure this acid discovered by Mr. Scheele, four apples are to be pressed, and the juice saturated with vegetable alkali. This liquor is to be mixed with a solution of sugar of lead. A double decomposition then takes place. The acetous acid seizes the alkali, while the malufian acid combines with the calx of lead. The malufite of lead falls to the bottom, and the precipitate, after being washed, is treated with diluted vitriolic acid. Vitriol of lead is thus formed, and the malufian

lusian acid is left disengaged. The vitriolic acid must be added in sufficient quantity to decompose all the malufite of lead, which may be known by the fresh acid taste of the liquor.

This acid possesses the following properties: It cannot be obtained in the concrete form. With the three alkalies it composes deliquescent neutral salts. With lime it forms a salt, affording small irregular crystals, soluble in boiling water, in vinegar, and in the malufian acid itself; with clay it forms a salt, scarcely soluble; with magnesia it unites in a deliquescent salt. It dissolves iron; the solution being brown, and incapable of crystallization. With zink it affords a salt in beautiful crystals. The nitrous acid changes it into the saccharine acid. It precipitates the nitres of mercury, of lead, and of gold, in their metallic state. Calcareous malufite decomposes ammoniacal citrate; and calcareous citrate is formed, which is insoluble in boiling water, and in vegetable acids. The solution of calcareous malufite in water is precipitated by spirit of wine. Lastly, the malufian acid is quickly destroyed by fire, which converts it into the cretaceous acid; this last saturates in part the bases of malufites, decomposed by heat. Such are the properties which establish the peculiar character of this acid.

Mr. Scheele has found this acid almost pure, or mixed with a small quantity of the acid

acid of citrons, in the juice of apples, of barberries, elder-berries, wild-plumbs, the fruits of the service-tree, plumbs, &c. He likewise found it united with half its weight of citronian acid in gooseberries, cherries, strawberries, raspberries, brambleberries, &c. and lastly, he has obtained it from sugar by means of the nitrous acid; and Mr. de Morveau observes, that the malusian acid appears before the saccharine acid.

When four fruits contain both the acid of citrons and the malusian acid, Mr. Scheele makes use of the following process to separate them, and to obtain the latter in a state of purity. The juice of gooseberries saturated with chalk gives a calcareous citrate, which being insoluble, falls to the bottom; the supernatant liquor holds the calcareous malusite in solution, which is separated by means of spirit of wine; but as it always remains united with mucilage, Mr. Scheele had recourse to another method for obtaining it in a state of purity. He evaporated the juice of gooseberries to the consistence of syrup, on which he poured spirit of wine, which dissolved the acid without acting on the mucilage. The latter, of course, was separated by filtration: the filtrated liquor being exposed to evaporation, and then saturated with chalk, the portion the citronian acid it contained was deposited in the form of calcareous citrate, while the calcareous malusite remained in solution. An
addition

addition of more spirit of wine precipitated it from this liquor, and he obtained the malufian acid by dissolving this salt in water, and precipitating the solution by acetated lead; after which the malufite of lead was decomposed by the vitriolic acid; the malufian acid by this means remaining in an uncombined state in the supernatant liquor.

Since the discovery of all these vegetable acids by Mr. Scheele, this celebrated chemist and Mr. Crell have observed an analogy between many of them. Mr. Scheele, who at first thought the acids of sorrel and of sugar very different from each other, has succeeded in shewing that they are one and the same acid; first, by removing a portion of vegetable alkali, which conceals the properties of the pure oxaline acid, in the salt of sorrel, in the same manner as the acid of tartar is altered in cream of tartar. Mr. de Morveau calls these two native acids, the one tartareous acidula, and the other oxaline acidula, on account of the portion of alkali they contain. To obtain the oxaline acid in a state of purity, Mr. Scheele precipitates its solution by the acetous salt of lead, and decomposes the oxalte of lead by the vitriolic acid: the liquid oxaline acid, which floats above the vitriol of lead, affords by evaporation crystals entirely similar to those of the saccharine acid. 2. Mr. Scheele proves this identity in an inverse way, by recomposing the salt of sorrel, or oxaline acidula

acidula, by pouring drop by drop a solution of vegetable alkali into the saccharine acid : During the effervescence, small crystals of salt of sorrel in a state of great purity are deposited. To succeed in this experiment, it is necessary to add but a small quantity of the vegetable alkali ; for an excess would form the oxalte of pot ash, which is entirely soluble. This fact may be shewn in a convincing manner, by pouring either the pure oxaline acid, prepared by the acetous salt of lead and vitriolic acid, or saccharine acid formed by means of nitrous acid into a saturated solution of oxalte or sacchart of pot ash. The excess of the one or of the other of these acids regenerates salt of sorrel, or oxaline acidula, which falls down. The latter, therefore, does not differ from the pure oxaline or saccharine acid, but by the portion of vegetable alkali it contains.

If to this very important fact of vegetable analysis, we add the valuable experiments of Mr. Crell, who has obtained the acid of tartar from the spirit of wine, has converted that acid into vinegar, and into saccharine acid, and this last into acetous acid ; we shall perceive that the saccharine and oxaline acids, and also the tartareous and acetous are very analogous to each other, being formed from one and the same base, and differing only in the dose of the oxygenous principle contained in each. It appears that the tartareous acid contains the smallest portion,

tion, that the saccharine or pure oxaline acid contains much more; and that the acetous acid contains the most of this principle. I cannot avoid thinking, that since these four vegetable acids, formerly supposed to be so very different from each other, have already been proved to have the same base combined with different doses of the oxygenous principle; we may expect by new discoveries to find a like analogy between many others, and especially between the citronian and malusian acid, which are so often found together in vegetable juices.

XIV. The spiritous fermentation, the simultaneous formation of the cretaceous acid, and of ardent spirit, the necessity of water and of a saccharine principle for the carrying on of this fermentation, authorize us to conclude, that the process itself is a consequence of the decomposition of water. The oxygenous principle of this liquid seizes the carbonaceous principle, with which it forms cretaceous acid. This becomes disengaged, and the inflammable gas remains fixed in combination with the oily base; which, with different quantities of the oxygenous principle, forms the tartareous, saccharine and acetous acids, and constitutes ardent spirit. This theory admirably explains why ardent spirit affords so large a quantity of water during its combustion; why it is changed by the mineral acids into the saccharine, acetous, &c. acids. We do not, it must be confessed, yet

understand how it passes into the state of æther; but it is probable that spirit of wine, in these operations, loses a portion of its inflammable gas, and that water is formed.

XV. Chemists at present begin to form probable conjectures respecting all the desiderata required by science for the formation of animal matters. Digestion appears to be a simple extraction or solution by the gastric juice; the fixation of the mephitic is one of the principal functions of the animal organism. The mephitic appears from the researches of Scheele, and especially Berthollet, to constitute the principal difference which exists between vegetable and animal matters, by contributing to the formation of the volatile alkali, which the latter substances give out so abundantly in distillation, and other processes. It is not yet decided in what manner the mephitic becomes fixed in animals, whether by means of the stomach, the skin, &c.

The different animal fluids designed to maintain the various organs, the distinction between the gelatinous and albuminous fluids, and the fibrous parts dissolved in certain fluids, is at present well established. It is now well known that the first is the least animalized substance, that the second is more so, and that the third is the last product of the vital action on the fluids; that the first forms the solid parts, that the albuminous part becomes thick, and concretes by heat, while the gelatinous substance

substance is more disposed to melt, but at the same time more quickly re-produced. Peculiar acids have been found in the excrementitious humours, whose formation is unknown; especially that of the phosphoric acid, so abundantly and universally dispersed through this kingdom.

The nature of animal solids has been much attended to by modern chemists. The difference between the fibrous parts of the muscles, and the membranous coverings of certain parts, &c. is known. The art of medicine may expect from chemical discoveries the solution of problems relative to the formation of the several matters which constitute these parts; and especially respecting the phosphoric acid, the albuminous fluid, the fibrous matter, calcareous phosphat, and the peculiar oils found in the animal kingdom. The formation of the volatile alkali suspected by Bergman and Scheele, and put out of doubt by Berthollet, encourages us to hope that these problems will be resolved in due course. It is probable that a few principal facts only are wanting to enable us to arrive at several results of the greatest importance; and this hope ought to animate such physicians as are aware of the importance of chemical enquiries.

XVI. Ever since the time of Lord Chancellor Bacon, the importance of chemical researches on putrefaction, for medical purposes, has been well known. Several physicians

ficians have buſied themſelves on this ſubject to good purpoſe; but the cauſe of this decomposition, and the manner in which it is effected, has not yet been diſcovered. Modern experiments, however, have thrown ſome light on this important ſubject. It is ſuſpected that water, which favours, and even gives riſe to putrefaction, is decompoſed in the inteſtine motion, which conſtitutes that proceſs. The volatile alkali, ſo abundantly formed by the union of mephitic and inflammable air, is commonly very ſenſible. The ſlowneſs with which fat is decompoſed, its preſervation, and increaſed rigidity, which in certain caſes is very conſiderable, ariſes from the fixation of the pure air of water; the volatization and reduction of the elastic fluids, of animal ſubſtances deprived of life, expoſed to the air, and in a word, the complete ſeparation of all theſe principles, and their diſſipation in the atmosphere, which tranſmits them to new combinations; and more eſpecially the ſucceſſion of combinations and transformations from one kingdom to the other, ſo well expreſſed by Beccher in his philoſophical motto, “*circulus æterni motus*,” by which he expreſſes the never-ceaſing activity of nature, are among the various ſubjects we may expect to ſee explained by the enlightened chemistry of modern times.

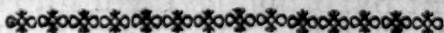
E L E M E N T S

OF

NATURAL HISTORY

AND OF

C H E M I S T R Y .



P A R T I .

General Facts and Observations.

C H A P. I.

Definition of Chemistry; the methods of performing operations; the advantages derived from this Science, &c.

CHEMISTS are not generally agreed on the most proper definition of Chemistry. Boerhaave, in his Elements, seems to have ranked it among the arts; or, to speak more accurately, he has defined only the practical part. Chemistry, according to Macquer, is a

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2 DEFINITION OF CHEMISTRY.

science, whose object is to discover the nature and properties of all bodies, by their analyses and combinations; and this definition is indisputably the best that has yet been given. But as it is certain that the analysis and synthesis cannot with equal success be employed in all cases where bodies are to be examined, would it not have been better to have omitted mentioning them in defining this science? The chemist cannot arrive at the knowledge of the properties of bodies, but by bringing them into contact; and as the result is derived only from the mutual actions of bodies on each other, we think the following definition may be properly adopted: Chemistry is a science which teaches the mutual actions of all natural bodies on each other*. The facts hereafter to be related, will illustrate this definition. To exhibit the extent of this science with perspicuity and order, we shall proceed to consider the objects or substances to which its researches or operations are directed, the methods or means employed, and the advantages proposed to be thence derived.

§ 1. Concerning the object, the methods, and the intention of chemistry.

The objects to which the attention of the

* This is too general; as it includes mechanical actions. T.

chemist

chemist is directed, comprehend the whole of the substances that compose the globe we inhabit, whether buried in its interior parts, or found at its surface. Chemistry is, therefore, of equal extent with natural history, the same limits being common to both.

Analysis, or decomposition, and synthesis, or combination, are the two methods which chemistry uses to accomplish its purposes. The first is nothing more than the separation of bodies, whose union formed a compound substance. Cinnabar, for example, is composed of sulphur and mercury; the art of chemistry separates the two, and by that means analyzes it. Till very lately it has been generally thought, and there are still many persons who retain the opinion, that this method is more advantageous in chemical researches than the other. This opinion had even acquired such place in the minds of the learned, that many writers have defined chemistry to be the science of analysis. But nothing can be more contrary to the accurate and well founded idea or degree of estimation we ought to have of decomposition. In order to shew this important truth in its proper light, it is necessary to distinguish two kinds of analysis; the true, or simple; and the false, or complicated. We call that the true analysis, by which the principles of a body are obtained,

tained, without having themselves suffered any alteration. The only distinguishing criterion of this is, that by recombining them, a body is again produced, absolutely similar to that which before was analyzed. Cinnabar will again furnish us with an example. When by chemical methods, the two substances which enter into the composition of this body, namely mercury and sulphur, are separated, they are found to be in a state of purity, similar to that they possessed before, when united in the form of cinnabar; for, by uniting them, a body is again formed, in no respect differing from the cinnabar originally made use of. Unfortunately for the progress of science, this kind of analysis is very rare. Chemists are not so happy as to be able to apply it to many of the bodies they make experiments with; for except the neutral salts, and some other mineral bodies, there are no other substances in nature that admit of its application. The false, or complicated analysis, is that, by means of which, no other principles are separated from a body, but such as in their original state possessed some other form, and consequently cannot, by their re-union, compose again the body from which they were obtained. This kind of decomposition takes place in most of the bodies analyzed by chemists; no other condition being requisite, but that more than two principles enter into the
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the combination to be examined, and that they have an affinity for each other. Many minerals, and all vegetable and animal matters without exception, are capable of no other kind of analysis. Thus it is that sugar, submitted to distillation in a retort, affords an acid, an oil, and a coaly residue, which might in vain be employed in attempts to re-produce sugar by combination. This kind of analysis does not shew the state in which the principles were before their separation, and cannot therefore afford any considerable information; but, on the contrary, deserves to be attended to with the greatest caution. From results of this kind have arisen all the censure chemistry is loaded with. It has been urged, that bodies were deprived of their organization, and absolutely destroyed in attempts to arrive at their principles. Neither can it be denied, but that this censure has been for a long time deserved; but at present, the science of chemistry, having become more circum-spect and enlightened, refuses its assent to the deceitful analysis to which it formerly had recourse, and possesses the means of inquiring into the properties and component principles of bodies, without destroying or altering their nature.

Synthesis, or combination, which constitutes the second method of prosecuting chemical inquiries, the formation of a

compound by the artificial re-union of several principles. Its utility, extent, and the dependance that may be placed on the results it affords, renders it by much the most valuable method. We may even affirm, that there is not a single operation in chemistry, in which some combination does not take place. Chemists do not seem to have sufficiently attended to this important circumstance. In fact, the synthetical operations, or events, are not only more frequent, but more useful, than the analytical; and it would afford no very inadequate idea of chemistry, if we were rather to term it the science of combination, than of analysis.

Though these two methods are sometimes employed separately, it is nevertheless much more usual to find them united. It often happens, that a true analysis cannot be made, but by the help of some combination. False analyses, or decompositions, are always attended with synthetical processes, or new combinations. In a word, it is not unusual to find, that a kind of analysis follows as a consequence from certain acts of combination; an event, which has not been known till very lately. The discovery of a great number of aeriform fluids, whose existence was not formerly so much as suspected, has shewn, that in many operations which were supposed to be simple combinations, an elastic

elastic invisible fluid is disengaged with effervescence, and either escapes into the atmosphere, or is received in vessels, in which the ingenuity of modern philosophers has taught us how to confine it. The greater number of combinations of two substances, hitherto thought to be simple, exhibit this kind of analysis; and frequent examples will offer themselves when we come to treat of neutral salts.

From this cursory account of the analysis and synthesis of the chemists, it is easy to be seen, that the whole art of chemistry consists in promoting the mutual actions of bodies on each other, and carefully observing the phenomena that take place. It must not be forgotten, that these two methods are continually practised in the grand operations of nature, of which the chemist is only an imitator. The operations all depend on laws established between bodies, and require nothing more, in order to their being perfectly accomplished, than that the bodies to be examined be put into a situation proper to act on each other. These important truths require to be maturely weighed and considered with the most serious attention, by the student who is desirous of penetrating into the depths of chemistry: and these, together with other truths explained in this first part, form the basis of the science.

Hence it is very easy to form an idea of

the end or intention of chemistry, which is erroneously said to consist in the discovery of the principles of bodies. For it is clearly shewn, that there are many bodies that cannot be separated into principles, but are simple substances, as far as our present knowledge extends; yet these, though not susceptible of analysis, must have chemical properties, or powers of acting on other bodies, and of forming combinations with them. The true purpose or intention of chemistry therefore, is to inquire into the action of natural bodies on each other, as well and even more, by synthesis than by analysis. This consideration serves completely to establish the property and truth of our definition.

§ 2. Concerning the useful purposes to which chemistry is applicable.

To give a view of the numerous advantages mankind derive from this science, would require a separate treatise; and as the nature of this work does not admit of our pursuing that subject at large, we shall content ourselves with exhibiting the principal outlines, and dwelling more particularly on such subjects, as in our opinion have not been seen in a proper point of view.

The great number of arts that are indebted to chemistry, may be ranged under
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two principal divisions. The first comprehends all the mechanical arts, which are reducible to geometrical principles. The second contains all those arts, whose manipulations depend on chemistry, and may be properly termed chemical arts. This last class is much more numerous than the other. As they are all founded on chemical phenomena, it is easy to imagine that the rules of chemistry ought to direct the practice, and that this science may simplify the processes by new discoveries, render their success more certain, and even extend their limits. Among these are, 1. The arts of making bricks, tiles, and the varieties of pottery; all which consist in the preparation of different kinds of clay, and bringing them by baking to the requisite degree of hardness. 2. The art of glass-making, which by uniting a vitrifiable earth with a saline substance, produces a new substance possessing great hardness, transparency, and durability, on exposure to the air. A wonderful art, which, in its various applications, has been of the most essential service to mankind. 3. The arts of extracting metals from their ores, of casting, of purifying, or of alloying them with each other, owe their origin and progress to chemistry, and daily receive new advantages from the same source. 4. The vegetable kingdom affords materials to a great number of arts, which, like the foregoing, are under the

the dominion of chemistry: the arts of converting saccharine juices, or farinaceous bodies, into vinous liquors; of extracting from those liquors the ardent spirit they contain; of separating the spirit from the water, with which it is diluted in its first state; of uniting this spirit to the aromatic parts of plants: the art of extracting the colouring matter of plants, and applying it to different stuffs: of changing wine into vinegar, and uniting this last with various substances; of separating from grain, and other parts of vegetables, the precious matter destined to form bread, a digestible and light substance prepared from a dry and insipid farinaceous powder; all these arts, and a very great number of others, that cannot be enumerated in this place, are entirely chemical, and are indebted to that science for their present perfection, and, in many instances, for their first invention.

This valuable science has claims equally extensive and important on the arts that convert the parts of animals to our use and advantage. Among these is the useful, though too little considered, art of cookery, whose true purpose is less to flatter the organs of taste by capricious variations of form and flavour, than to render aliments of easy digestion, by developing their taste by boiling, or by mild and natural seasoning. Some readers will, doubtless, be surprised to find the art of cookery, which is ordinarily
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thought of so small consequence, placed in the rank of those which chemistry is capable of advancing. It will be sufficient on this occasion to answer, that all the processes used in the preparation of food are chemical; and that it is not beneath the chemist, to pay some attention to an art that so materially affects the health. The arts of dressing, tanning, and currying skins, and of making hats, are of the same class; but one of the most important arts which occupies the middle rank between the arts, properly so called, and the sciences, is pharmacy. Every person concerned in pharmacy, has need of a very extended knowledge of chemistry, in order to know the alterations the matters he uses are subject to, that he may prevent and correct them; to discover the changes compound medicines undergo; and, in a word, to determine instantly, the combinations and decompositions that may follow from the mixture of simple drugs in extemporaneous prescriptions. Every impartial person who reflects on this subject, will determine, that such as are necessarily employed in pharmacy should, after acquiring the previous knowledge of natural history, indispensable in becoming acquainted with the *Materia Medica*, pay the most serious and unremitted attention to chemistry. By these means, and by these alone, it is, that the art of medicine can be reduced to principles,

12 USEFULNESS OF CHEMISTRY.

ciples, and rendered equal to the performance of those services, which have long since placed it in the honourable estimation of society.

A very transient prospect of the sciences, will sufficiently shew the great benefits to which they may derive from chemistry. Natural history is among those that receive the highest advantages from it. The characters employed by the early naturalists to distinguish minerals, were taken only from their physical properties, as colour, form, consistence, &c.; but these properties being subject to great variation, the bodies mentioned or described by the ancient philosophers are no longer known, and the immense labours of the first naturalists are almost entirely lost. The moderns have perceived, that in order to avoid this inconvenience, so destructive to the progress of natural history, it was necessary to follow another method. The method of chemical analysis appeared to deserve the preference; and the business is already in such forwardness, that classes are established among minerals, founded on the nature and quantity of the principles which enter into their composition. It is to the labours of Messrs. Bergman, Bayen, Monnet, &c. that we are indebted for the advancement of this part of natural history. Wallerius, Cronstedt, and several other learned men, began
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the task of classing mineralogy upon chemical principles. M. Bucquet, in his latter courses of lectures, improved on the knowledge these two celebrated naturalists have transmitted to us, by adopting a method of classing minerals, on principles entirely chemical. M. Sage, who has analyzed a great number of minerals, has followed a method purely chemical in his disposition of these bodies; and, though his theory is not yet universally received, it is certain that mineralogy is under great obligations to him; and that he ranks among those who have cultivated it with the greatest success in France. M. Daubenton has availed himself of the labours of all his cotemporaries, and has adopted their methods and conclusions with that caution, which is the true character of a philosopher, whose only aim is to discover and obtain the truth, separated from the numerous uncertainties and errors, with which, unhappily for mankind, it is too often attended. Nothing, therefore, can be shewn more evidently, than the advantages resulting from the application of chemistry to natural history, as it is the only means of removing that obscurity that must attend simple descriptions of external appearances. The just and truly valuable observation of M. Daubenton, deserves to be constantly attended to by all chemical philosophers. He warns them to be very careful in describing the specimens on which
they

they make their experiments, in order that they may be understood by all naturalists, and to avoid that confusion, which, according to that celebrated professor, prevails throughout the works of many modern chemists. M. Bucquet, and myself, have found no other means of avoiding this error, than that of uniting both sciences in our lectures, and associating the knowledge obtained from the works of naturalists, with that which chemical experiments daily produce.

It is not so clearly determined in the opinion of the world in general, that chemistry is useful in medicine. The errors of the chemical physicians of the last century, and the indifference many practitioners of the present time seem to have for this science, have produced a disadvantageous opinion in the minds of many persons, which time alone can remove. In the mean time, however, it would be more prudent, instead of entertaining an ill-founded prejudice, to inquire with impartiality into the cause of the errors committed by chemists, into the means of preventing them, and of restoring to chemistry that estimation it has unjustly been deprived of. If the enthusiasm of the first physicians, who cultivated chemistry, misled them, it does not follow that any conclusion can be drawn from thence that may be applied to the present time. The exactness which the moderns have introduced into

into every part of experimental philosophy, ought to remove the apprehensions of such, as for want of acquaintance with the subject, are apt to imagine that chemistry is still the dark, mysterious science it was a century ago. By a due attention to the extent of its powers, and a careful use of them, there cannot be a doubt but it will be found of the highest utility to medicine. After this acknowledgment of the wanderings of the early chemists, let us finish the justification of the science, by enquiring what departments of medicine are capable of deriving the greatest advantages from its assistance. The two great branches of this vast science, are theory and practice; which ought not to be separated from each other, as some authors have thought fit to do. The study of medicine ought necessarily to commence with the anatomical history of man, and of animals. Anatomy can only be employed on the solids. But physiologists must be well aware, that the greatest part of animal bodies is formed of fluids; by the motion of which, life is maintained. If therefore the attention were confined to the vessels, without attempting to arrive at the nature and properties of these fluids, we should be acquainted only with a part of the living œconomy. It belongs to chemistry to examine them; and it is chemistry alone, that can throw any light on their composition,

tion, and the changes they undergo, by the processes there are carried on during life. We cannot avoid having recourse to this science, in our endeavours to discover the true mechanism of the animal functions; the properties of the fluids separated by the different viscera; or the alterations such fluids undergo, during their time of remaining in the reservoirs into which they are secreted. A knowledge of the composition of animal fluids being once acquired, it will be necessary to enlarge and multiply our researches on subjects of different age, sex, and temperament, in various climates and seasons; and to pursue them among the different classes of animals; that by establishing useful points of comparison, the limits of science may be extended.

The labour of the medical inquirer is not confined to the study and examination of the properties of animal fluids in a state of health; but requires to be carried farther. The kinds of alterations they are subject to, in the several disorders that afflict the human frame, must be inquired into. A discovery what part of the animal liquids predominate in inflammatory, putrid, scorbutic, or scrophulous disorders; or the analytical knowledge of the saline substances developed, and the nature of the extravasated matter, with numberless other objects of research, cannot but be of the utmost value

value and importance in the science of medicine. We think it equally necessary to examine the solids, by chemical methods, as well in the sound as in the diseased state, and, by a comparison of their properties, endeavour to discover to which of the fluids they owe their formation; and this being known, we may proceed to conjecture in morbid dispositions, the solid or fluid that has suffered a change. This position, which we slightly mention in this place, will be more largely explained in the chapters relating to animal matters.

If it be thus established, that the theory of medicine is capable of receiving the most essential advantages from chemistry, it is equally certain that the practice is no less in need of the same assistance; since both must of necessity accompany each other, and are promoted by the same means. And, in fact, it is easy to shew the immediate dependence of the practice upon the science we are justly commending, without having recourse to the secondary advantage the practical part of medicine cannot but receive from every real improvement of the theory. To begin with the art of preserving health: nothing can be more evident than that the choice of aliments, and of air, cannot be made with any certainty, but in consequence of chemical researches into the nature of foods, and the properties of the atmospheric fluid.

fluid. Chemists alone can inform us of the quantity of nutritive matter contained in the aliments we make use of; the state it is found in; the nature and quantity of the substances it may be combined with; the means of extracting, purifying, and preparing it, suitably to different stomachs; or of giving it the due degree of attenuation appropriated to every constitution of the internal parts. It is to this science that we must apply for information, respecting the nature of the fluids that serve us for drink; the properties which water ought to possess for the purposes of life, and the means of examining into its purity, or discovering those substances that vitiate it; the principles and properties of fermented liquors; and the methods of examining into their composition, as well to determine their salubrity, as the adulterations which they may have undergone. In a word, it is chemistry which shews the properties of the air which we respire, and without which, life could not for a moment be supported. The changes this subtle fluid is liable to, from various agents, and the nature of those agents, the truly precious means of correcting its bad qualities, and rendering it fitter for the grand purpose of respiration, are among the discoveries of modern chemists.

The physician ought not to make use of
medicines,

medicines, unless he is acquainted with their nature; and in the inquiry, he must have recourse to chemistry. This truth has been always so well established, that writers on the *Materia Medica* have classed the medicaments according to their chemical principles. The observation of all ages has shewn, that there is an intimate connection between the taste of drugs, and the manner of their acting on the human frame: so that a good judgment may be formed of the medical properties of a substance from its taste. Thus it is that bitters are stomachic, insipid substances are mild and relaxing, and acid matters are active, penetrating, and incisive. Now, as the taste is truly a chemical property, depending entirely on the tendency of bodies to combination, as we shall elsewhere shew, chemistry must of course be of great service in the administration of medicines. It must not, however, be concluded according to the chemists of the last century, that the stomach resembles a vessel, in which operations are performed as in a chemical laboratory; where acids, for example, meet and effervesce with alkalis. The intestines are endued with sensibility, and a peculiar motion, that modify the nature and effects of remedies; and the discretion of an enlightened observer, ought always to regulate his imagination, so as to prevent his falling into any ridiculous hypothesis. It cannot be

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denied,

denied, but there are cases wherein medicines act in the first passages by means of their chemical properties; and in these cases the physician may reason and conduct himself according to immediate deductions from chemical principles. Thus it is proved, by long experience, that in the diseases of infants, the stomach and intestines are coated with a tenacious viscous matter, of a manifestly acid nature. The absorbent earths, and even the alkalis administered on such occasions, destroy this acid by combining with it, and form a neutral purgative salt that evacuates this noxious matter, by stimulating the intestines. Every disorder which is attended with an accumulation of obstructing matter in the first passages, necessarily demands a knowledge of chemistry in the exhibition of medicines. But the greatest advantage the practitioner can derive from this knowledge, is, without doubt, in those unhappy cases, wherein by mistake or design, corrosive substances have been taken that might prove mortal by attacking the viscera, and destroying their organization. Chemistry then lends its ready and inestimable aid to medicine, by affording substances capable of changing the nature of the poison by decomposition; or of otherwise immediately stopping its pernicious effects. The work of M. Navier, a celebrated medical chemist of Chalons, points out

out the most efficacious means of preventing the destructive consequences of the poisons of arsenic, corrosive sublimate, verdegriſe, and the preparations of lead ; and notwithstanding the declamations of certain phyſicians, who ſeem deſirous of excluding the ſciences from the practice of medicine, his work will receive the tribute of gratitude from poſterity.

Chemiſtry is not adequate to the counteracting the effects of all poisons, but there is good reason to hope that researches into the nature of vegetable and animal poisons, if made with ſkill and care, would be attended with the diſcovery of remedies of ſufficient power to counteract them. Opium, and all narcotic vegetables, the acid and caustic juices, ſuch as thoſe of ſpurge and euphorbium, the noxious plants, and more eſpecially the fungi, demand the particular attention of chemiſts, for the diſcovery of ſubſtances proper to obviate their dangerous effects. With no leſs utility, an inquiry might be made into the animal poisons. We are already acquainted with the acid of ants, from the experiments of Margraaf and Fontana. Thouvenel has diſcovered ſeveral acrid matters in cantharides. Mead has made researches on the poison of the viper. Fontana has purſued the ſame ſubject, and has diſcovered that the lapis causticus immediately introduced into the

wound made by this reptile, decomposes or alters the poison, and prevents its deadly effects.

If it be possible, after what has been said, to suppose that chemistry is not equal to the performance of the desirable effects here pointed out, yet no one can deny that the science of medicine is indebted to it for many useful remedies. It can never be forgotten that stibiated tartar, with all the mercurial, antimonial, and martial preparations which are possessed of such power and efficacy, are the products of chemistry; and that the gratitude and encouragement of medical professors, as well as the public in general, is due to such as devote themselves to its improvement.

To conclude our observations on the utility of chemistry to medicine, we shall only add, that a knowledge of the former is necessary, in order to draw up a prescription for any compound medicine to be made up by the apothecary. It happens daily, that persons unacquainted with chemistry, commit the grossest errors in their extemporaneous formulæ, by mixing together substances that either become changed by mutual decomposition, or else refuse to unite at all. In the case of decomposition, the medicine cannot produce the effect, which the physician from his acquaintance with the component matter, was led to expect. Such errors, so prejudicial to the health of the patient,

patient, are no otherwise to be avoided, but by a knowledge of chemistry, which is the only guide in the preparation of remedies. Without this guide, the physician is not only liable to the occasional faults we have pointed out, but to numberless others, which though of less essential consequence, must expose his ignorance to the apothecary; who, in the practice of his own art, cannot but be acquainted with a considerable number of chemical facts.

The usefulness of chemistry in the arts, and the resemblance between its processes and the manipulations of artists, have often caused it to be confounded either with alchemy or pharmacy, by persons ignorant enough to unite objects in their own nature so remote from each other. In the opinion of such, the chemist is an artist incessantly employed in the vain search of the philosopher's stone. But those who have acquired the least knowledge of true chemistry and its purposes, will readily perceive the immense distance between the ridiculous and absurd pretensions of the alchemist, and the enlightened chemist; and more especially the difference between the regular proceedings of the latter, compared with the inconsistent and useless processes of the former. The error of the many, who regard chemistry as the art of preparing drugs, is much more pardonable; because

it does not confound chemists with the ignorant, and, at best, the useless operators of what is called the Grand Work, who, as Macquer ingeniously observes, are the workmen of an art that has no existence; but associates them with a respectable class of artists, whose labours are necessary to society. But pharmacy being nothing more than a part of chemistry, or one of the many arts that are dependent on, or benefited by, its principles, the person who regards chemistry as the art of preparing remedies, will have but a very limited idea of this experimental science: a science of such sublimity and vast extent, that it not only contains within itself the much greater part of the numerous arts that distinguish civilized nations from savages, but extends its researches universally to the mutual actions of the component parts of bodies on each other; to the great improvement of natural philosophy, which in many of its most important parts is purely chemical.

C H A P. II.

The History of Chemistry.

HE who devotes himself to the study of any science, ought not to be ignorant of the outlines of its history. For such a history, being a relation of scientific facts, fixes the dates of discoveries, points out the errors of our predecessors, and indicates the path that leads to success. But as it might not tend to promote the immediate purpose of this treatise, if we were to dwell on subjects that are in some measure foreign to it, we shall exhibit nothing more than the outlines of this history; without entering minutely into particulars, which may be found at length in many well written books. In particular the treatise of Olaus Borrichius de ortu et progressu chemiæ, the article Chimie in the Dictionnaire Encyclopedique, the discourse at the head of Senac's Chemistry, l'Histoire de la Philosophie Hermitique by the Abbe Lenglet du Fresnoy, the first chapter of Boerhaave's Chemistry, the preliminary discourse to Macquer's dictionary, &c. may be consulted for this purpose.

For the purpose of exhibiting in a concise
and

and methodical manner, the progress of the human mind in the study of chemistry, and the several advances made therein from time to time, we shall divide our history into six principal epochas.

EPOCH A THE FIRST.

The origin of Chemistry among the Egyptians, and its progress among the Greeks.

The origin of chemistry is not less obscure than that of the other sciences and arts in general. The patriarch Tubal Cain, who lived before the deluge, is said to be the first chemist; but his knowledge is not affirmed to have extended beyond the working of metals. This man seems to have been the same, who is spoken of in fabulous history under the name of Vulcan.

It is among the Egyptians that we ought to place the true origin of this science. The first of this nation, of whom mention is made as a chemist, is according to Lenglet du Fresnoy, Thoth or Athotis, surnamed Hermes or Mercury. He was the son of Mezerai, or Osiris, and grandson of Cham. He became king of Thebes.

The second king of Egypt, who was likewise a philosopher, was named Sephoas. He lived 800 years after Athotis, and 1900 before Jesus Christ. The Greeks have given him

him the surname of Hermes, or Hermes Trismegistus. He is the second Mercury, and is esteemed as the inventor of natural philosophy. Several historians have transmitted to us the titles of his works on philosophy, which consisted of forty-two books. It does not appear that any of them treated of chemistry, though the science has been called after him, the Hermetic Philosophy.

Our information respecting the cultivation of chemistry in Egypt, is very uncertain. It seems, however, that this science made great progress in that country, since the Egyptians were in possession of a great number of chemical arts; and in particular, that of imitating precious stones; of casting and working metals; of painting on glass, &c.; but the chemistry, as well as the other arts and sciences of this ancient people, are lost. Their priests concealed them from the vulgar as mysteries, and only recorded them under the veil of hieroglyphics. The alchemists have persuaded themselves that some traces of their pretended art is to be found among these; and that the temple, which the Egyptians consecrated to Vulcan, was in honour of alchemy.

The Israelites learned chemistry from the Egyptians. Moses is placed in the number of chemists, because of the knowledge by which he was enabled to dissolve the idol of gold that people adored. It has been thought, and Stahl has

has written a dissertation to prove it, that this solution of gold in water was performed by the help of liver of sulphur; a process which supposes a knowledge of chemistry of considerable extent.

Democritus of Abdera, who lived about 500 years before Christ, travelled into Egypt, Chaldea, Persia, &c.; and it is affirmed, that he became acquainted with chemists in the first of these countries. Though the son of a man sufficiently rich to receive and entertain Xerxes and all his attendants, he returned very poor to his own country, where he was received by his brother Damassus. In his retirement in a garden, near the walls of Abdera, he employed himself in researches into the nature of plants and precious stones. Cicero affirms, that in order that he might not be disturbed from his speculations by external objects, he destroyed his sight, by keeping his eyes for a time fixed on the bright reflection of the solar rays, from a vessel of polished copper; a fact which, however, is denied by Plutarch. Pliny had so great a degree of esteem and veneration for the knowledge of Democritus, that he even thought it miraculous.

There are some authors who reckon Cleopatra among the chemists, because she knew how to dissolve pearls. They affirm, that the art of chemistry, well known to all the Egyptian

Egyptian priests, was constantly practised by that people, till the time of Dioclesian, who according to Suidas, thought fit to cause their books to be burned, that he might subdue them with more facility.

EPOCH A THE SECOND.

The Chemistry of the Arabians.

After a long series of ages, during which it is not possible to follow the progress of chemistry through the revolutions of empires, we find some traces of this science among the Arabians, who cultivated it with success.

During the dynasty of the Achemides or Abassides, the sciences, which had been long abandoned, were restored to their vigour. Almanzor, the second Califf, devoted himself to astronomy. Harun Raschid, the fifth Califf, and cotemporary with Charlemagne, caused several books relating to chemistry to be translated from the Greek.

In the ninth century, Geber of Thus, in Chorazan, a province of Persia, wrote three works on chemistry, in which we find things treated in a very confined manner. His best treatise is intitled, *Summa perfectionis magisterii*. He has written with considerable perspicuity on distillation, calcination, and the reduction and solution of metals.

In

In the tenth century, Rhases, a physician of the hospital at Bagdat, first applied chemistry to medicine. Some of his pharmaceutical prescriptions are still in esteem.

In the eleventh century, Avicen, a physician, likewise applied chemistry to medicine. His merit and knowledge raised him to the charge of Grand Vizier; but the debauched life he led was the cause of his being degraded from that office.

EPOCH A THE THIRD.

The transition of Chemistry from the East to the Western parts of the world during the Crusades. The reign of Alchemy.

The art of making gold was in request for a long time, according to the authors who have written concerning it; but the folly which gave birth to it was at its height during the interval between the eleventh and sixteenth centuries. The chemical facts discovered by the Egyptians, collected by the Greeks, and applied to medicine by the Arabians, came to the knowledge of the four nations who travelled into the east during the crusades; namely, the Germans, English, French and Italians; and each of these nations became immediately filled with searchers after the philosopher's stone. As the immense labours to which they devoted themselves have contributed greatly to the advancement

advancement of chemistry, it is necessary to be acquainted with such of these extraordinary men as have most distinguished themselves.

During the thirteenth century, Albert the Great, a Dominican of Cologne, and afterwards of Ratisbon, acquired the reputation of being a magician, and has left a work full of alchemical processes.

Roger Bacon, born in 1214, near Ilchester, in the county of Somerset, studied at Oxford. He repaired to Paris to study the mathematics and medicine. Many inventions are attributed to him; any one alone of which would have been sufficient to have rendered his name immortal. Among these are the camera obscura, the telescope, gunpowder; he is affirmed to have made a self-moving chariot, a speaking head, a flying machine, &c. He was a cordelier, and was surnamed the admirable doctor. An accusation of magic being preferred against him, caused his brethren to imprison him. He retired to a house near Oxford, where it is said he worked in alchemy. Borrichius saw the house, which was still known by his name. *

Arnold of Villeneuve, born in Languedoc, in 1245, and died in 1310, studied medicine at Paris during 30 years. He wrote a commen-

* This house, as I am informed, was standing a few years since. T.

tary on the epistle of the Schola Salernitana. The alchemists esteem him as one of their greatest masters. Borrichius in the year 1664, saw one of his descendants, an alchemist, in Languedoc.

The fourteenth century. Raymond Lullius was born at Majorca in 1235, came to Paris in 1281, where he became the disciple of Arnold de Villeneuve. Robert Constantin affirms to have himself seen one of the Rose Nobles that were struck in the tower of London, out of the gold made by him, during the reign of Edward the fifth, in the years 1312 and 1313. He wrote some books on alchemy, in which are to be found some facts concerning the preparation of acids, or aqua fortis, and on the properties of metals.

The fifteenth century. Basilius Valentinus, a Benedictine of Erfort in Germany, was well acquainted with medicine and natural history. He composed a book on antimony, to which he gave the pompous title of "*Currus Triumphalis Antimonii*," which was commented on by Kerkringius. In this book we find a great number of antimonial preparations that have since been offered to the world under different new names, and have been administered in the cure of disorders with great success.

Isaacus Hollandus the father, and his son of the same name, have written books praised by Boerhaave, from which it appears, that they

they were acquainted with the properties of aqua fortis, and aqua regia.

All these authors have in general written in the most obscure and confused manner on the chemical art; and though they were acquainted with some processes of dissolution, extraction, purification, &c. their pretensions were greatly beyond their knowledge, and scarcely any advantage can be derived from their labours.

EPOCH A THE FOURTH.

The universal Medicine; Pharmaceutic Chemistry; Alchemy opposed, from the sixteenth to the middle of the seventeenth century.

The bad success of the alchemists, and the ruin of their fortunes and reputation, were so far from discouraging chemical enterprizes, that we find a prodigious number of persons during the sixteenth century, encouraged and supported by the enthusiasm of a Swiss physician, named Paracelsus, who was born near Zurich, in 1493. This impetuous man pretended that there existed an universal remedy. He substituted chemical medicaments in the stead of those of the Galenical pharmacy then in use, and cured many disorders by mercurial preparations, which were then deemed scarcely curable,

more especially those of the venereal kind. His miraculous cures seemed prodigious; but transported by success far beyond the bounds within which he ought to have confined himself, he publicly burned the books of the Greek physicians. He died in the midst of his triumphs in an inn at Saltzburgh, at the age of 48 years, after having promised himself immortality by the use of his secrets.

This folly, highly extravagant as it was, revived the ardour of the alchemists. Some among them, who vainly imagined they had succeeded in the discovery of the universal medicine, dignified themselves by assuming the new title of adepts. Such were, at the commencement of the seventeenth century,

1. The Rosicrucians, a kind of society formed in Germany, of which nothing more was ever known in France but the title, and whose numbers continued unknown. These pretended brothers affirmed, that they were in possession of the secrets of transmutation, of the universal science, and medicine; with the science of occult things, &c.

2. A Cosmopolite, named Alexander Sethon, or Sidon, who performed the work of transmutation before a person of the name of Haussen. This last related the fact to Vander Linden, the grandfather of the physician of that name, who collected a medical library.

3. Another

3. Another named Thomas de Vagan, born in England in 1612. He travelled into America, where Starkey received gold from him. He corresponded with Boyle. This is the same adept, who in France gave his powder of projection to Hevelius. The latter, after this pretended miracle, which was nothing more than an artful trick, wrote a dissertation "De vitulo aureo, &c."

The success that attended the administration of chemical medicines by Paracelsus, was productive however of some permanently good effects; for it induced several men of abilities to enter into the inquiry, and to write useful works on the preparation of chemical medicines. Such are the writings of Crollius, Schroder, Zwelfer, Glafer, Tachenius, Lemery, &c. and the Pharmacopœiæ, published by several faculties of medicine.

Glauber, a German chemist, about this time rendered an essential service to chemistry, in examining the residues of operations, which former operators had always thrown aside as useless, and distinguished by the names of caput mortuum, or terra damnata. By this means he discovered the salt named after him, and the vitriolic ammoniac; and threw great light on the chemical processes for preparing mineral acids, &c.

Some of the promoters of chemical science subsequent to Paracelsus, were not entirely cleared of the ideas his ungoverned imagination

tion gave birth to. Such were Cassius, known by his precipitate of gold; Sir Kenelm Digby, who believed in the sympathetic action of medicaments. Libavius, whose name is affixed to a preparation of tin. Van Helmont, famous for his opinions in medicine, and the chemical notions he has propagated. And, lastly, Borrichius, a Danish physician and chemist, who first discovered and published the method of inflaming oils by the nitrous acid, and is entitled to the respect and gratitude of the world for having bequeathed his library and chemical laboratory to the use of indigent students of medicine.

Alchemy, at that time, was in great danger from two celebrated men, who successfully combated its tenets. The one was the famous Kircher, a Jesuit, to whom we are indebted for a grand and sublime work intitled, *Mundus Subterraneus*; the other was the learned physician Conringius.

EPOCH A THE FIFTH.

The origin and progress of Philosophical Chemistry, from the middle of the seventeenth to the middle of the eighteenth century.

Chemistry had not hitherto been treated philosophically. The chemical arts had been described,

described, medical formulæ had been given, and the nature of metals had been laboriously inquired into with a view to the making of gold, or of the universal medicine; (delusive views which still mislead the ignorant and enthusiastic) but nothing more had been done. The facts ascertained were many, but no one had yet collected them, and, as the celebrated Macquer happily observes, there were many branches of chemistry in being, though the science itself was not yet in existence.

Towards the middle of the seventeenth century, James Barnet, physician to the king of Poland, arranged the principal known facts in a methodical manner, and added observations in his philosophical chemistry. The book of this learned man is the more valuable on account of his being the first person who attempted to form a complete body of chemistry, and ranked it among the sciences.

Bohnius, Professor at Leipzig, likewise composed a book of scientific chemistry, which had great success, and was for a long time the only elementary book on this subject.

Joachim Beccher of Spire, a man of the most extensive genius, physician to the elector of Bavaria, went far beyond the two authors last spoken of, and caused even their names to be forgotten. In his

sublime work, entitled "*Physica Subterranea*," he united all the known facts of chemistry, and described them with astonishing sagacity. He has even pointed out by conjecture, a great part of the discoveries made to this day; such as the aeriform substances; the possibility of reducing animal bones into a transparent glass, &c. This work was commented on by a celebrated physician, whose name fixes a most brilliant epocha of chemistry. J. Ernest Stahl, born with a strong passion for chemistry, undertook to comment and improve the doctrine of Beccher. His attention was more particularly directed to ascertain the existence of the inflammable earth, which he called phlogiston. Equal to Beccher in genius, but superior in accuracy of operation and order of research, he composed a treatise on sulphur, a work on salts, and another, entitled *Trecenta Experimenta*, which have gained him immortal glory, and placed his name among the first of his age.

Boerhaave, in the midst of numberless occupations, cultivated chemistry, and composed a celebrated and truly profound work on this science. His treatises on the four elements, and especially that on fire, are master-pieces to which it is scarcely possible to make any addition. He was likewise the first who attempted the analysis of vegetables,

vegetables, and discovered the spiritus rector, &c.

The theory of Stahl has been followed by the whole chemical world, and received a new accession of strength from the two celebrated brothers M. M. Rouelle, whose too early loss is severely felt by the science, and to whom chemistry owes its origin in France.

The illustrious Macquer, who will be long lamented by every lover of science, has contributed in a most eminent degree to the advancement of this science by his most excellent works, which are with the greatest justice esteemed in every part of Europe, as the surest guides to chemistry. Besides the great obligations the world is under to him for his Elements and Chemical Dictionary, his own particular labours and discoveries on arsenic, Prussian blue, dying silk, on clays for pottery, &c. are sufficient to immortalize his name, and entitle him to the gratitude of posterity.

EPOCH A THE SIXTH.

Pneumatic Chemistry ; the present time,

Stahl, intirely busied in demonstrating the existence of phlogiston, and following it through all its combinations, seems to have overlooked the influence of the air in the

greatest part of the phenomena in which he attributes so great an energy to the inflammable principle. Boyle and Hales had nevertheless already proved the great necessity of attending to this fluid, in the operations of chemistry. The former had observed the difference between the chemical events that happened in like circumstances in the air and in vacuo. The latter had obtained from a great number of bodies a fluid which he supposed to be air, but in which however he had observed several peculiar properties, such as odour, inflammability, &c. according to the various substances they proceeded from. He thought the air was the cementing principle, or cause of solidity in bodies.

Dr. Priestly, in repeating a great part of the experiments of Hales, has discovered many fluids, which, though they resemble air, differ from it in all their essential properties. And in particular, he obtained from metallic calces a kind of air, much purer than that of the atmosphere.

M. Bayen, a chemist so justly celebrated for the exactness of his operations and experiments, examined the calces of mercury, and discovered that they were reducible without phlogiston, and that during reduction they emitted an aeriform fluid in great abundance.

M. Lavoisier proved very early, by a great number of valuable experiments, that a portion

tion of the air becomes combined with such bodies as are calcined or burned. In consequence of this, he established a sect or class of chemists, who began to doubt the presence of phlogiston, and attributed to the fixation of air, or its disengagement, all the phenomena that Stahl supposed to depend on the separation or combination of phlogiston. It must be granted, that this doctrine has the advantage over that of Stahl in its proofs, being more strict, and is so much the more seducing, as it agrees better with the accurate and rigorous manner of proceeding, which is at present adopted in the study and cultivation of natural philosophy. This seemed to be the case in the opinion of the late M. Buquet, who in his two or three last courses appeared to give it the preference. The wisest, and doubtless the only proper conduct to be pursued on this occasion, is to wait till a great number of facts shall have completely demonstrated, that all the phenomena of chemistry are explicable according to the pneumatic theory, without admitting phlogiston. M. Macquer, though well aware of the great revolution these new discoveries could not but occasion in chemistry, did not admit the opinion, that every fact is explicable without supposing the existence of an inflammable principle; and instead of phlogiston, whose existence has never been fairly proved, he has substituted light, the
action

action and influence of which in chemical appearances cannot be called in question.

Strongly impressed with a conviction of the propriety and necessity of pursuing this mode of conduct, we shall be careful to explain both these doctrines: and confining ourselves to our province of the historian, we shall take no other liberty than that of remarking which theory seems to us to have the greatest probability of being true, in the facts to which we must necessarily apply them.

C H A P. III.

Concerning the Chemical Affinities.

IN the foregoing chapter we have observed, that the means used in the performance of chemical operations, which are in general referable either to analysis or synthesis, are founded in nature; and that chemists are no more than imitators. This truth will be more strongly established by the explanation of the chemical affinities which we are about to give.

The least progress in the study of natural philosophy is sufficient to impress the mind of the observer with a knowledge of that
wonderful

wonderful force established between bodies, by which they mutually attract each other. All the phenomena in nature are dependent on this law, which the philosopher contemplates with admiration, and the most uninformed inquirer cannot consider without some degree of perplexity and astonishment.

The smallest bodies, as well as the immense masses that are composed by their union, are alike subject to this force, so necessary for the preservation of the harmony of the universe: but its laws appear either to be essentially different, or differently modified, according to the mass, bulk, or resistance of the bodies acted on by its power. Without inquiring into its effects on the planetary * bodies, whose distances and motions it governs, let us observe what happens on the globe we inhabit, and endeavour to discover its laws of action.

Natural philosophy teaches us, that two solid bodies of the same kind, when in contact, adhere together with so much the more force as the surfaces at which they touch are

* The celebrated Bergman (*de Attractionibus electivis*) and others, as well as our author, from a wish to generalize, and in consequence of a too superficial view of the universal laws of attraction, have erroneously supposed that gravity, or the planetary attraction, might be so varied, when bodies became nearly contiguous, as to be modified or converted into the chemical affinity, or elective attraction observed between the minute parts of bodies. See Newtoni, Prin. I. § 13. T.

more

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more polished and extended. Thus two planes of glass, or two sections of a metallic sphere slipped upon each other with pressure, become united, and often require a very considerable effort to separate them. This effect is still more striking between two drops of a like fluid, such as water, oil, or mercury. Placed at a certain distance from each other, upon an uniform surface, we see them mutually attract, move towards* each other, and unite into one single globule. This force gives birth to all the phenomena observed in chemistry; and it is therefore of the highest importance to study with care, all the laws and circumstances that accompany it.

The greater number of chemists have denominated this force affinity, or relation, because it has been thought that it depended on an analogy or conformity of principles in the bodies between which it exists. Bergman has called it attraction, though its effects are very different from the planetary attraction observed by Newton; of which,

* I am persuaded the ingenious author has drawn this conclusion without making the experiment. Drops of water, or other fluids, are so far from moving towards each other at any sensible distance, that according to the law followed by all bodies not nearly in contact, they repel each other. Hence during rain, the drops may be seen rolling along the surface of water in all directions, and the effect is still more considerable in spirit of wine. T.

however,

however, it appears to be only a modification||, as we shall hereafter see. This affinity may take place between bodies of the same, or of different natures. Let us observe it under these respective points of view.

§ 1. Concerning the affinity that takes place between bodies of the same kind, or the affinity of aggregation.

When two bodies of the same nature, as for example, two globules of mercury placed at a certain distance from each other, tend by virtue of this force to unite, and the union is suffered to take place, a sphere of greater magnitude, but of entirely the same nature, is formed. This force, therefore, produces no change, except in the physical, or obviously apparent qualities of bodies. It joins together parts of the same kind, which before were separate; augments the bulk or magnitude by confounding the masses, and forms one simple body out of several. It is named the affinity of aggregation, to distinguish it from that between bodies of different natures. It produces an aggregate, in which, though the physical properties are changed, the chemical qualities are not sensibly altered. The aggregate is nothing more than a coherent body, whose molecules are united by

|| See the note on page 43.

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the force of aggregation. It must be distinguished from the mass called a heap, which, though consisting of parts of the same nature, has not coherence throughout; as well as from a mixture which is taken to denote an incoherent mass of dissimilar particles. An example will illustrate this. Flowers of sulphur, or sulphur in powder, whose parts have no adhesion, but may be separated by the smallest efforts, constitute a heap, on the parts of which, relatively considered, the affinity of aggregation does not act. If this be mixed with another heap, as of nitre in powder, a mixture by confusion will be had. But if by the help of fusion, the power of aggregation be caused to act, then the molecules, or integrant parts, brought towards each other during their liquefaction, unite and adhere together in such a manner, as, that when cooled, they form a single mass or solid, which is a true aggregate.

The force or affinity of aggregation has different degrees, measurable by the effort or power necessary to be employed in separating the integrant parts. We may distinguish four kinds of aggregates, under which all bodies in nature may be comprised.

1. The hard or solid aggregate, in which the force that unites the integrant parts is very considerable, and which cannot be destroyed, but by some very violent re-action.

There

There are many degrees of aggregation under this class, from the hardness of the precious stones or rock chrystal, to the softness of the most yielding wood. Its character is to form a mass, whose different parts cannot be sensibly moved amongst each other, without breaking or separation.

2. The soft aggregate is that, whose parts, tho' coherent, may nevertheless be slid upon each other by a small force, so as to change their respective situation. The force that unites the parts of a soft body, is less than in such as are hard; and less re-action is necessary to destroy it.

3. The fluid aggregate. Its integrant parts are so slightly united together, that the smallest effort is not only sufficient to cause them to slide, or change situation amongst, but also to separate them from, each other.

4. Lastly, the aeriform aggregate, whose integrant parts are too small to be perceived, and in which the affinity of aggregation is the least possible. The air of the atmosphere furnishes an example.*

These four kinds of aggregate are no more, properly speaking, than degrees of the same force, which it is nevertheless of great conse-

* The aeriform aggregate is here erroneously defined or described. It is that whose density is not sufficiently great, to afford obvious indications of its presence, and in which the affinity of aggregation is negative, causing the integrant parts to repel each other. T.

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quence to distinguish with care, because their state and diversity have a singular influence on chemical phenomena. This is proved in a very satisfactory manner, from the consideration that many bodies are capable of being successively put into each of these four states. Water in the form of ice is a solid aggregate. Its hardness is the greater in proportion as its temperature is lower; when exposed to the temperature of 32° Fahrenheit, it assumes a kind of softness† before it passes to a state of fluidity. This last mentioned state is well known in all climates; and philosophers have computed its force of expansion when in the state of vapor, or in the aeriform aggregation.

In proportion as we advance in the knowledge of the laws of affinity, we shall perceive still more the necessity of distinguishing and attending to these four kinds of aggregation. This is more particularly necessary in comparing the force of aggregation with the second kind of affinity next to be examined.

As these two forces, which seem to depend on the same cause or principle, are nevertheless always opposed to each other in chemical phenomena, so that it may even be inferred from the facts we shall exhibit, that

† Quere? T.

they

they are in the inverse ratio of each other, † it is necessary when the chemist wishes to cause the one to act, that he should diminish the other, or reduce it to nothing. Now the attractive force we are speaking of, is almost always that which he has occasion to diminish, and it is likewise modifiable at pleasure, by means in the power of the artist.

To destroy or diminish the affinity of aggregation, nothing more is required, than to oppose to the cohesion of the parts of the aggregate, an external force more than equal to that which retains them together, which consequently must be greater or less, in proportion to that adhesion. This is the leading principle in the preparatory operations, whose sole purpose* is to destroy the affinity of

† This opposition of the affinities of aggregation and combination, must rest intirely on the reasoning of the author in the following pages. To me it seems neither fairly deduced nor probable in itself. A variety of important circumstances, some of which are unknown, are included in this, and almost every other question, concerning the affinities. They cannot here be entered into; but the present may perhaps be decided, by answering the following. Are there not many operations in which an increase of temperature at the same time weakens both the powers of aggregation and combination, and the contrary? If this were not the case, could any separation be made by mere heat, without an intermedium? And if heat be matter, and be the intermedium in such cases, the affinity of aggregation, as it is called, is out of the question. T.

* The purpose is to increase the surfaces, that the mutual action of bodies on each other being carried on at the same time among a great number of parts, may be sooner finished, and the intended process completed. The affinity of

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of aggregation: pulverization, grinding, filing, rasping, cutting, are operations that oppose the coherence of solids, and serve to separate their parts. Filtration and evaporation produce nearly the same effect on fluids. The softening and fusion of bodies by heat, answer the same intention. These operations, whose detail belongs to the practical part of chemistry, are only mentioned here to shew the connection they have with the theory.

As art is possessed of numberless means of opposing the force of aggregation, so likewise it affords others for restoring, and causing it to act again with all its energy. All its manipulations for this purpose consist in placing the bodies, whose aggregation it is proposed to restore, in a state of division and fluidity, so that the particles of these bodies may be at liberty to obey the power of attraction, by applying to each other those of their surfaces which are best adapted to unite; and the regular figure and cohesion often equal, and sometimes even surpass, those of natural bodies of the same kind. On this occasion we must remark, that all aggre-

aggregation impedes combination in no other way than by covering the internal parts. A lump of sugar is slower in dissolving, if put into water, than the same quantity in powder, because in the former case the external parts must be dissolved and removed, before the internal parts can be acted on. T.

gate

gate bodies may be divided into two classes, namely, regular or irregular. Nature has given to every body the property of presenting itself under one or other of these two states; art, ever emulous, and often the rival of nature, can at pleasure produce either. All bodies capable of passing through the different states of aggregation before enumerated, and more especially salts and metals, may, according to the management of the artist, in their passage from fluidity to solidity, appear in the shape of an irregular mass, or in that of a body with regular facets, which is called a crystal. Nothing more is necessary to produce the former state, than to keep the particles whilst fluid, whether by heat or by water, very near each other, and to cause the liquefaction suddenly to cease, so that coming into contact all at once, they may unite into an irregular mass. But, on the contrary, crystallization requires that the parts of the bodies, in which it is to be produced, should be kept sufficiently distant from each other, that they may be as it were in equilibrium some time before they unite, and may mutually present to each other the surfaces that best agree with each other. After these details, it is clear that crystallization is entirely the consequence of the affinity of aggregation. It is in this point of view that we have here considered

dered it; and shall reserve our future observations on the subject, to the other parts of this work.

§ 3. Concerning the Affinity between two Bodies of different Natures, or the Affinity of Composition.

When two bodies of different kinds have a tendency to unite, they then combine by virtue of a force different from that we have hitherto spoken of, and which is named the affinity of composition or combination. This kind of affinity, more necessary to be understood than the former, takes place in all the operations of chemistry, none of which can be explained without it. This principle was known in the earliest times, but it was not attended to with sufficient care, till experience had shewn that its influence on the practice is equal to that on the theory of the science we are treating of. It is this doctrine that must guide the practitioner in the researches necessary for the advancement of chemistry, and must be consulted by the philosopher who collects and compares the facts. It is the compass by which both must steer; and it may be truly affirmed, that he who is intimately acquainted with the affinities, knows every thing that the most sublime chemistry has to offer.

Well

Well convinced of this truth, we shall endeavour first to collect with fidelity all the facts that relate to them, and afterwards to explain the hypotheses that have been invented, respecting their cause.

Observation, the parent of chemistry, as well as of every experimental science, has shewn, that the affinity of composition presents constant and invariable phenomena, which may be regarded as established laws, obvious to all but those who are unacquainted with the method of studying nature. These laws, founded on a great number of well established facts, may be reduced to the eight following.

First Law of the Affinity of Composition.

The affinity of composition does not take place but between bodies of different natures.

This first law is invariable, and subject to no kind of exception. In order that two bodies may combine, and form a compound, it is a necessary condition that they should be of different kinds. In fact, if two bodies of the same nature be united, the result will be nothing but an aggregate, whose mass and magnitude only will be augmented without the loss of any of its essential properties, and the union will be preserved by the affinity of aggregation, as has been already shewn. Thus two pieces of wax, resin, or
D 3
sulphur,

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fulphur, are united by heat. The difference between the affinities of aggregation and of composition may hence be easily conceived.

This law is so true and so constant, that the affinity of combination is never so powerful, as when the bodies, between which it is exerted, are of the most different kinds. Thus it is that acids, whose properties are so opposite to those of alkalies, combine and form the most perfect compounds with them. The same opposition of properties is observed between alkali and sulphur, alkali and water, acids and metals, spirit of wine and water, &c. all which have an exceeding strong tendency to combine with each other, and to form the most perfect compounds, though their nature is totally different.

It is still more necessary to attend to this leading principle, of the affinity of composition, because many chemists, with Stahl at their head, have endeavoured to prove, that bodies never entered into combination, but in consequence of a certain agreement, or resemblance of their properties; an opinion, which must of course be rejected, when the full extent of this law is understood. On perusing the writings of the greatest chemists on this subject, it is seen, that the resemblances they endeavour to find between substances that have a great tendency to unite, are always very remote; and that by following the same method, it is possible to find others equally strong between the most dissimilar

diffimilar bodies. It is, however, not difficult to observe, that these great philosophers were desirous of rendering the theory of affinities more intelligible, by means of this explication; and those who are aware of the extreme difficulty that attends the establishment of theory, in any branch of human knowledge, will be ready to consider their efforts with the gratitude to which they are entitled. Their works are of the highest utility, by the illustrative arrangement and connection of the facts they have brought together. But our first homage is due to truth, which compels us to avow our ignorance of the cause of this extensive similitude of facts which we offer as a law of nature, rather than to have recourse to an analogy, which is contradicted by examining into the properties of bodies.

Second Law of the Affinity of Composition.

The Affinity of Composition does not take place, except between minute Bodies.

In order to conceive this law as it really exists, it is necessary to distinguish those subjects concerning which the chemist reasons, from others properly called physical. The latter are bodies, whose exterior properties, such as mass, bulk, surface and figure, may be submitted to computation, and appreciated by the senses. The natural philosopher or mechanic is busied in the consideration of aggregates. Chemical subjects, on the con-

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trary, are bodies that have lost their aggregation, and consequently no longer exhibit the physical properties of aggregates to the senses. They are particles so subtle, that their figure and value cannot be known from measurement. Bodies do not obey the affinity of composition, till they have been reduced by the preparatory operations, to the requisite degree of minuteness. It seems as if this property were confined in its operation to the infinitely small particles, or ultimate molecules of bodies. Hence it appears, that the affinity of composition differs from the attraction subsisting between large bodies. This difference is still more striking, when we consider the opposition which is observed between the affinities of aggregation, and the affinities of composition. This opposition is so well established, that I can venture to advance, as a chemical axiom, that the stronger the affinity of combination, the weaker the affinity of aggregation. These two forces seem to be opposed to, and mutually to counteract each other. In fact, the affinity of aggregation opposes the combination of bodies, and therefore such as have a strong force of aggregation, have very little tendency to enter into combination; while substances, that have little or no aggregation, have, at the same time, a very strong disposition to combine with others. The various kinds of air, for example, are, among all
bodies;

bodies, those which have the weakest power of aggregation, and are likewise those which have the greatest disposition to unite with almost every other kind of body.

Lastly, To establish the leading principle, we shall not hesitate to conclude, that as there are many cases, in which the affinity of aggregation counteracts the affinity of composition; as in all solid bodies, such as metals, sulphurs, lead, saline crystals, &c. which cannot be united to acids, alkalis or water in their state of solidity; so there are likewise some cases, in which the affinity of composition not only opposes, but even destroys the force of aggregation. It thus happens, when we bring together two fluids that have a great affinity to each other, and at the same time tend to take the aerial or vaporous form; as the caustic volatile alkali, and the marine acid, when each exhales a visible fume, consisting of substance itself, whose aggregation is broken by the force of combination, and which approaches and comes into contact with the other neighbouring body. This phenomenon takes place when two glass vessels are placed near each other, containing the fluids above-mentioned. It is observed also between the volatile alkali, and the humid metallic salts. It often happens that these bodies, exposed in covered vessels several feet asunder, tend in such a manner to unite, that they escape in
visible

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visible vapours, whose direction carries them manifestly towards each other.

Third Law of the Affinity of Composition.

The affinity of composition can exert its action on more bodies than two.

This law of affinity is one of those we are least acquainted with, and has been hitherto but very imperfectly inquired into. Many affinities and combinations of two bodies are known. Fewer of three, and still fewer of four bodies united by equal affinity have been noticed. The metals alone present such combinations, and may be combined with two, three, or four. It is probable that combinations of more than four, as for example, six or eight bodies may exist; but art has hitherto thrown very little light on this subject. The cause of the slow progress of the study of this law, will be shewn when we come to treat of the eighth law. The affinity that may take place between many bodies is denoted by their number, by saying the affinity of two, three, four bodies, and so forth. The rapid advancement of modern chemistry, the multiplicity of researches that are pursued, and the scrupulous exactness of the present methods, give us reason to hope that these affinities, which are called complicated, will soon become better known.

Fourth

Fourth Law of the Affinity of Composition.

In order that the affinity of composition may take place between two bodies, it is necessary that one of the two at least should be in a state of fluidity.

This law has been long known to chemists, and is expressed by the following axiom, *Corpora non agunt nisi soluta*. The most connected and exact observations have shewn, that two solid substances cannot unite into combination with each other. Whence it happens, that bodies, which have the greatest tendency to unite, cannot effect it, unless one of them be in the state of fluid aggregation. The more fluid the bodies which the chemist is desirous of combining are, the less aggregative force they have, and consequently the more easily and intimately they may be united. It is for this reason, that no combination is more rapidly or more perfectly made, than when two aeriform bodies are brought into contact, as the marine acid air, and alkaline air.

Though two solid bodies can never combine, yet there are certain circumstances in which dry substances reduced to fine powder act with sufficient energy on each other, to unite and form a new compound. Thus I have observed, that the caustic fixed alkali unites when cold by simple trituration

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tion with sulphur, antimony, and kermes mineral, as I shall elsewhere describe; but in this case, the extreme division of the two bodies and the moisture of the atmosphere, attracted by the salt which soon deliquesces, are of singular advantage to the combination, and in fact bring it within the law we are treating of.

It is not always necessary that both the bodies we wish to combine should be fluid, but only that one of them should be so. During their union a phenomenon takes place, which chemists call dissolution or solution. It is the attenuation, division, and total disappearance of the solid body placed in contact with the fluid. To understand the cause of this phenomenon, it is to be considered, that the affinity of combination which exists between two substances, the one fluid, and the other solid (as for example, the vitriolic acid and a piece of calcareous spar) is stronger than the affinity of aggregation that unites the particles of spar, and causes it to possess a solid form. Now, since by the third law this affinity cannot take place but between small bodies, it becomes a necessary condition that the spar must be reduced into very small particles by the loss of its aggregation, before it can unite with the vitriolic acid, and form selenite. The ancient chemists in all solutions made a distinction between the solvent, and the body intended to be

be dissolved; the former being the fluid, and the latter the solid. This distinction, which supposes in the fluid a force superior to that existing in the solid aggregate, cannot be admitted by modern chemists, who observe with M. Gellert, that in solution the action is equal on both sides, and that in the example here cited, the vitriolic acid would not destroy the aggregation of the spar, if this last did not tend to combine with the vitriolic acid with an equal force. The term solvent, at present applied to fluids, is therefore far from being chemical, and presents to the mind the idea of a mechanical action; for which reason it would be better to reject it altogether. But as custom has unfortunately prevailed, it becomes necessary to remember, that when one body is said to dissolve another, nothing more is intended to be expressed, than the state of fluidity of the former; and that no greater activity is attributed to it than to the solid, which possesses exactly the same force.

The false idea that has till lately prevailed concerning solution, has doubtless arisen from the mechanical theory of this operation of nature, which certain philosophical chemists have invented. This theory, which is found in every page of Lemery, consists in supposing the solvent an acid, for example, to be an assemblage of very acute points, and
the

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the body to be dissolved as possessing an infinite number of pores, in which the points of the acid are received, which tear asunder its parts, and by that means reduce it to such a state of division, as to cause it to escape the sight. It is sufficient to exhibit the opinion; the more accurate and less hypothetical method of cultivating philosophy, which is now universally adopted, will save us the trouble of confuting it.

Fifth Law of the Affinity of Composition.

When two or more bodies unite by the affinity of composition, their temperature changes at the instant of their union.

This phenomenon has appeared so constantly to attend every operation that art can perform, that we have thought proper to consider it as one of the laws of the affinity of composition. The temperature of bodies during combination, may be altered by the production of either heat or cold. The latter takes place much oftener than the former; but as cold is produced in many synthetical operations, we have expressed this phenomenon, by the words "change of temperature."

It may be objected, that there are certain solutions or combinations slowly effected, in which no change appears. To this we answer,

answer, only by requesting that they will plunge a very sensible thermometer in these solutions, and they will be convinced that a change of temperature takes place, which is almost always warmer than that of the atmosphere.

This phenomenon seems likewise to depend on the change of the aggregation of the substances that become combined, in their passage from solidity to fluidity, according to the observation of Beaumé, of which we shall elsewhere speak. But as this change of aggregation is a consequence of the action of the affinity of combination, it is evident that this last affinity is the cause of the change of temperature.

M. Macquer was of opinion, that the variations in the temperature of bodies that enter into combination, depended on the motion the particles are put into; but if this explanation be admitted as sufficiently indicating the cause of heat in cases in which it is observed, it certainly does not explain other cases, wherein cold is produced. Some modern chemists, and in particular Scheele and Bergman, are of opinion, that heat, which they esteem as a peculiar substance, is greatly concerned in chemical combinations, producing cold when absorbed, or heat when disengaged. Though this theory explains very well the changes of temperature that takes place when bodies unite,

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unite, it is nevertheless subject to very great difficulties; the chief of which, as we shall prove when we come to speak of fire, are founded on the consideration, that the existence of heat, as a peculiar substance, is by no means demonstrated.

Sixth Law of the Affinity of Composition.

Two or more bodies, united by the affinity of composition, form a substance, whose properties are very different from those of any one of the bodies before their combination.

This law in particular requires to be well proved, because many celebrated chemists of the present age have entertained notions respecting compounds, which by no means agree with the greater number of facts, and are directly opposite to what we here offer, as one of the principal and most remarkable of the phenomena attending the affinity of composition.

Stahl and his followers, whose abilities in other respects have been of such important service to chemistry, have affirmed, that compounds always partake of the properties of the bodies that enter into their composition; and that their properties are intermediate between those of their principles. They have even carried this notion so far, as to imagine that it was possible to conjecture, from the properties of a compound, the nature

nature of the bodies that compose it. From considerations of this kind it was, that Stahl pronounced salts to be composed of earth and water, because he thought he observed in all salts, properties intermediate between these two substances. As we propose to discuss this doctrine when we arrive at the part of our work that treats of salts, we shall make no observations on this example in this place, but shall content ourselves with observing that the chemists, who have followed Stahl in this opinion, have not had better success than himself in their proofs; and that the intermediate or mean properties which they have pretended to discover in compounds, have seldom any but the most remote agreement with those of the substances that constitute the combination. This observation we shall establish from the consideration of the very instances that are urged by Stahl himself. And we cannot here avoid remarking the difficulty which that author appears to have met with in establishing this opinion in his writings, and the embarrassment which prevails in his explanations. These considerations engaged M. Bouquet and myself to examine this theory with attention, and induced us to adopt another directly opposite to it.

In reality, nothing more will be necessary to prove the existence of the law concerning which we are now treating, than to

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point out instances of compounds whose properties are entirely new, and have no kind of relation to those of their component parts. The history of every chemical combination tends to support our position, and there is not a single fact which will not furnish matter for its proof. We shall therefore select a few striking instances in well known combinations, from which it will follow : 1. That bodies, which enter into combination, lose the properties they before possessed. 2. That they acquire new properties totally different.

Let us fix, then, in order to proceed with method, upon such properties, as if varied, will affect the senses very considerably in consequence of such variation. The taste is often very considerable in two simple bodies, and when they are combined, they have a very faint or feeble taste when compared with that before possessed by either. Vitriolated tartar, which is produced from the union of two strong caustics, oil of vitriol and pure salt of tartar, has only a bitterish taste, which can by no means be regarded as intermediate between the two caustic salts. On the contrary, two bodies that have little or no taste may acquire a very pungent one by their union. Mercury and the marine acid, given separately in a dose of a few grains in a glass of water, are not capable of producing any noxious effect

effect on the animal economy; while the same dose of corrosive sublimate formed by the union of these substances, and administered in the same vehicle, is one of the most violent poisons, and of a most corrosive taste.

The affinity of composition has a singular influence on the form. It often happens, that two matters, that are not susceptible of crystallization alone, assume a regular form when they are united, as is the case with the marine acid air, and alkaline air, which in the instant of their union constitute crystals of sal-ammoniac. In other cases, the form is simply changed and modified, as in the union of certain neutral salts with each other, and in metallic alloys, which exhibit, according to Abbé Mongez, crystallizations somewhat differing from those of the metals in a state of purity. Lastly, bodies very susceptible of crystallization alone, lose this property when united with other bodies; as metals united with air, and some of them when united with acids.

The same observations, in proof of the law we offer, may be made with regard to consistence. It is seldom the same in a compound, as in the principles that compose it. Thus it is found that two fluids, united with each other, suddenly produce a solid, as is seen in oil of tartar added to oil of vitriol; and that from the union of two solids there frequently results a fluid, as in

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neutral salts combined with ice, and in the mixture of an amalgam of lead with an amalgam of bismuth.

The colour is frequently altered in combination. Sometimes it disappears, as when the coloured marine acid is added to a metal, the solution is transparent. Very often two bodies assume a deeper colour than before, in consequence of their union; as when iron or copper are dissolved in most acids, or lead, mercury, and most of the metals united to pure air, and in the state of metallic calces.

It is frequently found that two bodies of very pungent smell form, by uniting, a substance without smell; as the marine acid air and alkaline air already mentioned, both which have a suffocating smell, but in their union form sal-ammoniac, which has scarcely any smell. Again, from inodorous bodies a compound mass arises, whose smell is strong; as is observed when sulphur and fixed alkali form the very fœtid substance called liver of sulphur.

We may proceed to the consideration of fusibility. Two very infusible substances may become very fusible when united. Combinations of metals will melt with the heat of boiling water, and combinations of earths will flow into glass; but the simple substances themselves are much less fusible.

The foregoing facts are far from being the only

only ones which might be urged in support of this law. There are many other that will offer in the course of chemical reading, which it will not be at all difficult to apply.

Seventh Law of the Affinity of Composition.

The affinity of composition is measured by the difficulty of destroying the combination formed between two or more bodies.

Chemists are acquainted with methods of separating bodies in combination with each other; but these methods are more or less easy, and differ in their degree of complication or simplicity. In observing the appearances that take place in these processes, it is constantly seen that the more perfect the compound, the more difficult it is to separate the principles, and destroy the composition. The degree of difficulty experienced in making this separation, may therefore serve to shew the adherence, or affinity, that exists between bodies respectively.

We insist the more strongly on this law, because it is easy for beginners to mistake in estimating the difference of affinity that obtains among the several bodies they combine together. The rapidity with which certain bodies unite, may naturally produce a conclusion that the adhesion between them is very strong. Long experience, however, has shewn that this rapidity, so far from in-

dicating the more perfect combinations, rather shews a weak adhesion, and produces only a very imperfect compound. In order, therefore, to fix with exactness the degree of affinity with which bodies combine and remain united, we must have recourse to the measure of the difficulty experienced in separating them, or destroying their union. The examination of the eighth and last law will clear up this matter.

Eighth Law of the Affinity of Composition.

All bodies have not the same force of affinity with respect to each other; and it is possible from observation, to determine the degree of the force existing between different bodies.

All bodies have not an equal tendency to combine with each other. There are some which absolutely refuse to unite, or at least cannot be directly united by art, as iron and mercury, water and oil, &c.; though it cannot be thence inferred that there is no affinity between them; other substances unite with great difficulty, and after a very long time.

But the most important circumstance in the variety of affinity is, that as this force is not equal amongst all bodies, it is practicable from the knowledge and application of this phenomenon, immediately to effect the separation

separation of two bodies, whose union forms a compound. It is even certain, that the most essential part of the art of chemistry consists in producing such decompositions, by means of which, it works a kind of miracle in the eyes of such as are unacquainted with them. To explain this, let us suppose two bodies to adhere together, with a force denoted by the number four, as for example, an acid and a metal; and let a third body be presented, which has an affinity to the acid equal to five or six, as for example, an alkali. What will be the consequence? The alkali, which tends to unite with the acid, by virtue of a force superior to that which joins the same acid to the metal, must separate the latter, in order to seize the acid. As this in fact takes place, the metal is separated, and a new combination is formed between the acid and the alkali. This decomposition is denominated precipitation, because the matter separated commonly falls to the bottom of the fluid.

The matter that falls to the bottom is called a precipitate, and the substance added is called the precipitant. Precipitates may be distinguished into four kinds. The true precipitate is formed, when one of the principles, such as it existed in the compound, is separated, and falls down. Thus when selenite, formed by the combination of the

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vitriolic acid and quick-lime, is decomposed by the addition of the pure fixed vegetable alkali, which has a greater affinity with the acid, the lime is separated, and, falling to the bottom, constitutes a true precipitate. There is a false precipitate obtained, when the new combination, formed between the precipitant or substance added and one of the principles of the compound, falls to the bottom by reason of its insolubility, and the separated matter remains in solution. Thus in decomposing the nitrous solution of mercury by the marine acid, with which that metallic substance has more affinity than with the former acid, the new combination of mercury and marine acid falls to the bottom of the vessel, forming a false precipitate, above which the nitrous acid remains dissolved in the water. This difference depends only, as we shall see elsewhere, on the difference of solubility of the matters.

It may easily be seen, that the erroneous denomination of this last example tends to mislead beginners. It is certain that those, who gave the name of precipitate to the substance separated from the compound by the precipitant, ought not to have applied it also to the new combination produced in the latter case. But even supposing that the name precipitate were confined to the matter separated by the precipitant, it would still be productive of error, because there are
many

many cases in which the separated matter, so far from falling to the bottom, rises and is volatilized. This happens when the combination of marine acid and volatile alkali is decomposed by quick-lime, which has a greater affinity to the acid than the volatile alkali has; the latter flies off in vapour, and no precipitate is found in the mixture. To avoid this confusion of nomenclature, it would be proper to substitute the name of decomposition, instead of that of precipitation: but as the custom has prevailed, we preserve the usual names, first pointing out the errors to which they may give rise.

It is sufficiently clear, that a liquid must be present in the operations that afford the precipitates we have spoken of. In this case the precipitation is said to be effected in the humid or moist way, in order to distinguish it from that which is made in the dry way, or by fire, and which is effected either by fusion or distillation; operations that will be explained at length in the following part of this work.

Modern chemists have likewise distinguished with much more propriety two other kinds of precipitates. These are pure and impure precipitates. The first comprehend all bodies which, after having been separated from the compounds of which they were before a part, regain all their former properties, and

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and appear to have suffered no alteration, either in consequence of their having entered into a combination, or of their subsequent separation. This number of this kind of precipitates is very considerable, though that of the impure kind is still greater.

That a precipitate may be very pure, it is necessary, not only that it shall have suffered no change in becoming part of a compound, but likewise that it shall have no affinity with the precipitant. For example, when spirit of wine is poured on a solution of vitriolated tartar in water, the spirit of wine, which has more affinity with the water than it has with the salt, separates the latter; and the vitriolated tartar falls down in a state of purity, because it has suffered no alteration from the water it was combined with, nor with the spirit with which it cannot unite. But if two bodies are mutually altered in their union, as is the case when metals are combined with acids, then the third body employed to separate them, as for example an alkali, will precipitate the metal in a state widely different from that which is natural to it, and by that means exhibits an impure precipitate. The same thing happens, if the precipitant has any tendency to unite with the precipitate; as in the example already cited of a metallic solution decomposed by an alkali, a part of this last salt may combine with the metal, and render it impure.

pure. These two causes of the impurity of precipitates are almost always united; whence it happens, that one of the most certain methods of discovering a false precipitate, exclusive of the absence of the essential properties it ought to possess, is to add a much greater quantity of the precipitant than is necessary to destroy the combination, and the excess, by combining with and dissolving the precipitate, will cause it to disappear. By pouring the volatile alkali on a solution of copper in the nitrous acid, the copper is precipitated in the form of flocks of a light blue colour. The colour of this precipitate, far from resembling the metallic brilliancy of copper, immediately shews it to be an impure precipitate. This is still more confirmed by the addition of more volatile alkali. This salt dissolves again the blue precipitate, the liquor gradually resumes its transparency, and assumes a beautiful blue colour, which indicates the combination of the calx of copper with the volatile alkali.

The exact knowledge of these impure precipitates, which present themselves much more frequently than the pure, is due to the researches of M. Bayen on the decomposition of mercurial solutions by alkalis, and the state of the precipitates obtained in these operations.

After the foregoing explanations, it will
not

not be at all difficult to understand the theory of decompositions, as effected by the addition of a third body to a combination of two. As there seems to be a kind of choice or preference between one of the principles of the compound, and the substance added, in consequence whereof the separation of the two first takes place, Bergman has adopted a name very well calculated to afford an exact notion of the fact: he calls this force elective attraction.

Beginners will not find the same facility in understanding what passes in the more complicated phenomena called by chemists double affinities, and by Bergman double elective attraction. It often happens, that a combination of two bodies cannot be destroyed by a third or a fourth body separately, though if a compound of the two last were presented to the former, a mutual decomposition would take place. An example will render this clear. Vitriolated tartar, or the combination of the vitriolic acid with fixed vegetable alkali, cannot be decomposed either by the cold nitrous acid, or by lime, if presented singly. But if to a solution of vitriolated tartar be added the neutral salt formed by the union of the nitrous acid and lime, the two combinations are mutually decomposed; the nitrous acid seizes the vegetable alkali, and forms nitre, while the vitriolic acid, uniting with the lime, forms selenite; which,

which, being much less soluble than the nitre, falls to the bottom. The explanation of this remarkable phenomenon is as follows. The vitriolic acid, united with the vegetable fixed alkali, cannot be decomposed by the nitrous acid, nor by lime; because its affinity with the alkali is greater than that of the nitrous acid or lime, either to itself, or to the alkali: But when the compound of nitrous acid and lime is presented, the tendency of this last acid to the alkali of the vitriolated tartar, together with that of the vitriolic acid to the lime, is greater than the attractions that lead to preserve the original forms. To render this still clearer, let us assume numbers to express the forces. Suppose the vitriolic acid to adhere to the alkali, with a force denoted by 8; the nitrous acid tends to unite with the alkali with a less force, which therefore we may call 7; and therefore cannot singly effect the decomposition. Again, if on the other side, the tendency of the lime to unite with the vitriolic acid be assumed for the same reason to be 6, no decomposition will take place by its being singly presented. But if nitrated lime be added to vitriolated tartar, there will be an opposition of attractions to each other. The first attraction 8, tending to preserve the original form of the vitriolated tartar, will be opposed by the two attractions 7 and 6 equal to 13, tending to decompose it; and therefore,

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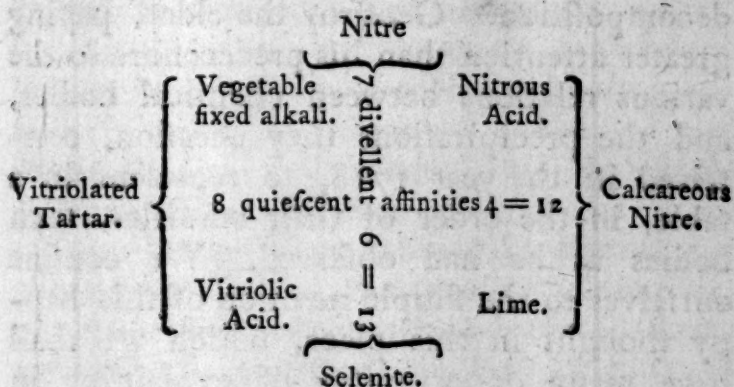
therefore, if the attraction tending to preserve the form of the other compound, nitrous acid and lime, be less than 5, or the difference of 8 and 13, a double decomposition will follow. So that if this last attraction be 4, the principles will arrange themselves so as to satisfy the greater attraction of 7 added to 6, instead of the less of 8 added to 4. The combinations will therefore be nitrous acid with alkali, and vitriolic acid with lime.

In double affinities there are therefore two kinds of affinities, which it is necessary to distinguish. 1. That by virtue of which the principles of each compound adhere to each other. Mr. Kirwan calls this first force the sum of the quiescent affinities, because it tends to preserve the union of the principles in their original form. 2. That by virtue of which, the four principles change their order, and form new combinations. Mr. Kirwan calls this second force the sum of the divellent affinities, because it is capable of destroying the effect of the former. By the help of this useful distinction, we may very easily shew what happens in the decomposition and new combinations by double affinity, by forming a table after the manner of Bergman. For this purpose the two compounds, that mutually decompose each other, are to be placed between two braces opposite each other, so that the acids may be opposed to the bases they exchange, and by adding together

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gether the numbers expressing the force of affinity the four bodies have for each other, the two horizontal numbers will give the sum of the quiescent affinities, while the two vertical numbers will exhibit the divellent affinities by which they are opposed. If the sum of the latter exceeds that of the former, a double decomposition and combination will follow. By applying the method to the preceding example, its utility and precision will be easily seen.

EXAMPLE.



I have explained ten examples of double decompositions that take place in mixing neutral salts, in my *Memoires et Observations de Chimie*, vol. 1. p. 308 and 438.

Chemists have not, till very lately, attended to the double affinities; and the instances wherein they take place are far from being

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being all known. They, who employ themselves in chemical researches, will continually observe this kind of decomposition in circumstances where no such event has been suspected. Many occasions will present themselves in the history of saline matters, in which we shall observe these affinities, as lately discovered by Bergman, Cornette, and ourselves.

We cannot quit the explanation of this tenth and last law of affinity, without taking notice of the ingenious method, first contrived by a French chemist, to exhibit at one view, the leading phenomena of chemical decomposition. Geoffroy the elder, paying greater attention than his predecessors to the various relations between chemical bodies, and the precipitations they occasion, contrived in the year 1718, to represent in a table, in the order of their affinities, such bodies as he had observed. We confine ourselves to the simple mention of this happy thought in this place, which we shall have many opportunities of explaining in the course of the present work. Geoffroy offered his table to the public, as an essay to which he foresaw it would be necessary to make great additions and alterations. Many chemists have adopted and extended his plan. Rouelle the elder made some corrections in his table, and added several columns. M. de Limbourg, a physician at Spa, in an excellent

cellent dissertation, which gained, in conjunction with M. Sage of Geneva, the prize proposed in 1758 by the academy of Rouen, has constructed a table of still greater extent. Gellert, in his Metallurgic Chemistry, has also given a new one. But no one has advanced this part of chemistry more than M. Bergman, professor of chemistry at Upsal. This celebrated chemist has made a distinction between the affinities that take place in the dry and in the humid way. He has given two very large tables, in which he shews the affinities between most bodies in nature. We are likewise indebted to the same philosopher for a very ingenious table, in which he has found means, by a peculiar disposition of the chemical characters, to present a view of the phenomena of double affinities; of which an example has just been given.

After having thus exhibited the principal phenomena of the affinity of combination, and established the laws by which this force appears to be governed, we shall proceed to take notice of certain cases in which these laws seem to be subject to variation. We shall not here enter into a detail of the facts on which this assertion is grounded, because it is our intention to remark them carefully wherever they occur. We shall, therefore, only observe, that the apparent inconstancy of the laws of affinity depends

solely on certain modifying circumstances; as the quantity of matter, the temperature of the atmosphere, motion or rest, solution by water or by fire, that is, by the humid or dry way, the particular state of aggregation, &c. Bergman has considered all these circumstances with singular care and attention, and has explained the various apparent changes they are capable of producing in the laws of affinity. And from the whole of the facts which he has collected on this subject, he has concluded that these variations ought not to be regarded as exceptions, and are by no means sufficient to weaken the evidence on which the doctrine of affinities is founded.

This shews the opinion which ought to be entertained of two other kinds of affinity admitted by certain authors. The one is the affinity of intermedium, and the other the reciprocal affinity. By the first, they understand that which causes a body in combination with another to unite with a third, though it would not have united with this last, if it had not previously been combined with the former. Oil, for example, will not unite with water; but where the oil is combined with a salt, a soap is produced soluble in water, by the medium of the saline matter. It is not, however, the salt that renders the soap soluble, because it does not exist in the combination with all its saline properties; but it is to the new properties
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of the compound soap, that its solubility in water is to be referred. This phenomenon is intirely dependent on the eighth law of affinity, which declares, that compounds possess properties intirely new and different from those of their component parts.

The reciprocal affinity takes place when a compound of two bodies is decomposed by a third, and the separated principle is capable of decomposing the new combination in its turn; so that there seems to be a sort of reciprocity in the effects. So, for example, it is found that the vitriolic acid has a greater affinity with the fixed alkali than the nitrous acid has, and that it decomposes the combination of this alkali with the latter acid. Nevertheless, the nitrous acid can in its turn separate the vitriolic acid from the alkali, since it is certain, that by heating vitriolated tartar with nitrous acid, nitre is again formed. This kind of affinity admitted by M. Beaumé, is to be attributed solely to the circumstances that produce a change in the forces. For it is in fact necessary that the nitrous acid should be hot, to decompose vitriolated tartar, and the nitre formed in this operation is again decomposed by the vitriolic acid, when the mixture becomes cold. The fuming or phlogisticated nitrous acid decomposes vitriolated tartar in the cold; fuming spirit of salt effects the same decomposition according to the observation of M.

Cornette; but Bergman has with great reason observed, that the fuming acids, which he calls phlogisticated, have other affinities than the same acids simple, pure, or de-phlogisticated.

In every case of this kind, the order of the affinities is changed and modified by particular circumstances. The other facts whereon Beaumé founds his proof of the reciprocity of affinities, as the decomposition of sal-ammoniac by chalk, and of the calcareous marine salt by concrete volatile alkali, belong to the double affinities, as we shall shew when we come to speak of these salts.

Nothing remains at present to conclude our discourse on the affinities, but to exhibit the opinions of some philosophers on the cause of this force.

Those philosophers, who first attended to the subject, attributed it either to the similar figure of the elementary molecules, or the physical configuration of the parts; or lastly, to a certain occult relation of their intimate composition. These early notions are necessarily connected with the mechanical explications that embarrassed the science of natural philosophy in its infancy.

The greater number of such modern philosophers, as have endeavoured to explain the cause of affinity, have observed an analogy between this force and the Newtonian attraction. Persuaded that nature is simple and uniform, they

they concluded that the property of mutually uniting must depend on that of attraction, which all bodies are known to possess. They have formed a comparison between the small bodies which are acted on by the affinities, and the large masses that compose the universe; and have considered the approach of the former to each other to combine, as a consequence of their mutual gravitation. It is by adopting and modifying this opinion, that certain writers have concluded that the force of affinity follows the ratio of the weight, and that the heaviest body possesses the power of combination in the strongest degree. This hypothesis sometimes agrees with facts,* as may be observed with regard to many acids, especially in their action on metallic substances. Lastly, some chemists have been so firmly persuaded, that there is the most perfect relation between attraction and chemical

* This hypothesis cannot be brought to the test of experiment, and must therefore rest, like many others, intirely on its analogy with the phenomena that suggested it. The force of affinity may depend on, or be proportional to, the specific gravity of the particles; but that specific gravity has no sort of relation to, and consequently is not deducible from, the specific gravity of the aggregate. To mention one, among innumerable instances in proof of this assertion; it is found that fixed air composes more than one third of the weight of calcareous spar, whose density is nearly three times that of water; but when disengaged, occupies many hundred times the former space. Can the specific gravity of its particles be inferred from either state? Certainly not. T.

affinity, that they have imagined it possible to measure and compute its force from the adhesion that takes place between bodies. M. de Morveau, whose opinion is of such authority as to lead that of other philosophers, has made some experiments with a view to prove this assertion. These experiments consisted in applying to the surface of mercury, metallic plates of equal diameter, suspended from the arm of a balance, whose other extremity carried a dish as usual. In this last he placed weights, till their force became equal to the separation of the metallic plate from the surface of the mercury; and he found by comparative trials with different metals, that their adherence to the mercury was various, and agreed sufficiently near with their affinities with that fluid. That is to say, he found that gold adhered the strongest of all to the mercury, while cobalt, which is scarcely capable of uniting with it, was raised very easily from its surface, with which it has little or no adhesion. We must here take the liberty of observing, that experiments of this nature are subject to error, because the lower surface of the metal must combine with the mercury; and the portion of amalgam formed in these circumstances being naturally more considerable where the metal unites the most readily with the mercury, will then add most to the weight, and consequently require the greatest force
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to lift it up from the surface of the mercury. This objection seems to be sufficiently forcible to deserve the attention of the celebrated author of these experiments.

It is evident, from what has been here related concerning the opinions of philosophers, that the cause of the attraction of affinity is very far from being known; and that if it be the same with the attraction of gravitation, the difference of the laws which it follows, compared with those of gravity, shew that it is peculiarly modified. This truth may be easily ascertained, by comparing the knowledge we possess concerning the attraction admitted by Newton, with that which we begin to have concerning chemical affinities. In reality, the former does not sensibly shew itself, but between large masses, and is in the direct ratio of the quantities of matter; whereas the latter is not observed, but between very minute bodies, and is absolutely insensible when the bulks are considerable. The former exerts its power at immense distances; but the latter does not exist but between bodies in contact, or nearly so. We have already exhibited a part of the comparison, in examining the laws of the chemical force we are inquiring into; and we believe after all these reflections, that the difference between these two natural phenomena is sufficiently marked to render

it incumbent on philosophers to make a distinction between them.

If we might presume to give our sentiments on this subject, we think that it is as impracticable in the present state of our knowledge to discover the cause of the chemical affinity, as it has hitherto been to assign that of gravity, magnetism, &c. ; and that the sciences will be much more promoted by examining, without intermission, the appearances that present themselves, and by multiplying the laws, if possible, than by indulging in speculations, which are always uncertain, and too frequently founded in error.

C H A P. IV.

Concerning the Principles of Bodies.

PHilosophers in every age have admitted, that all the variety of natural bodies are formed of primary substances, more simple than themselves, which they have distinguished by the name of principles. Chemists, who have the strongest conviction of this leading truth from their analyses, have formed ideas, sufficiently precise, of the nature and difference of these principles ; and have even admitted of several kinds or classes

classes. It must, however, be remarked, that they use the word principle in a different sense from that adopted by the ancient philosophers. For Aristotle and Plato did not regard any substances as principles, but such as are too minute to be perceived by the senses, and form, by their assemblage, bodies somewhat less simple, which are within the sphere of perception, and were by them called elements; a name still retained, and applied in the same sense. These are what other philosophers have called atoms, or monades. But chemists, not chusing to enter rashly into speculations of such subtlety, apply the term principle in general to all bodies, whether simple, or more less compounded, which they obtain in their analyses. Yet as principles, considered in this point of view, are very different from each other, they have divided them into proximate and remote principles. The first are such as are separated by a first analysis, and may themselves be composed of others; as for example, in decomposing a vegetable substance, oils, mucilages, salts, and colouring matter, are separated from each other, and are the proximate principles from which, by new operations, other principles may be had. These other are the remote principles. Thus mucilage, which is a proximate principle of plants, affords by a new analysis,
acid,

acid, water, and earth, which are the remote principles of the plant. Other names have also been given to these two orders of principles, such as principiated principles applied to those before called proximate, and principiant principles to those called remote. These words imply, that the first are composed of other principles, and that the last are such as serve to form or constitute others more compounded. Some chemists, for greater accuracy of distinction, admit several orders of principles. They call the most simple by the name of primitive, primary, or first principles. Principles composed of the most simple kind united are called secondary, or principles of the second order. Principles of the third order are composed of this last, &c.

The number of elements has not been always the same among philosophers. Some with Thales the Milesian, who was placed in the rank of the seven sages of Greece, on account of his uncommon acquisitions in knowledge, and who, according to Cicero, was the first of the Grecians who applied himself to natural philosophy, have regarded water as the principle of all things. According to Anaximenes, air occupies this first place, and he did not scruple to deify this element, on account of its great importance. Others bestowed the chief dignity upon the earth; the leader of whom was Anaximander, the disciple of
Thales,

Thales, and master of Anaximenes. Every one found reasons to support his own opinion; but as the true method of conducting chemical and philosophical inquiries was not then known, we can only esteem these early notions as speculations, void of all foundation. About three centuries after the time of these philosophers, Empedocles, a physician of Agrigentum, thinking that the simplicity of the four substances contended for as the principle of all things to be equal, united their opinions, by admitting of four elements, fire, air, earth, and water. In the succeeding age, Aristotle and Zeno, adopted this opinion of Empedocles. When we reflect on the reasons that may have engaged these philosophers to regard fire, air, earth, and water, as elements, we are tempted to believe, that it was not so much in consequence of the accurate knowledge they could have acquired concerning these bodies, as in consideration of the magnitude or quality of them, and the constancy or invariability of their properties. Fire exists every where, and its effects are always the same. Our globe is surrounded by a mass of air, whose essential properties do not seem subject to variation. Water is presented to observation on the surface of the globe, in an immense mass, that fills up or conceals its abysses or cavities. And lastly, the globe itself, whose volume far exceeds that of all the creatures
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that inhabit it, seems to be formed of a solid matter, little subject to change, capable of fixing or serving as a base for the other elements. It appears, therefore, that it was from considerations, founded on the bulk and apparent immutability of these bodies, that the early sages were induced to regard them as the materials used by nature in the formation of all other beings.

The peripatetic doctrine which prevailed in the schools, preserved the Aristotelian distinction of elements, till the sixteenth century. At that period, the sect of chemists, which began to prevail against the others, admitted a new division of primary substances. Paracelsus, who was more of the artist than of the philosopher, drew immediate inferences from the results of his operations, and acknowledged five principles; spirit, or mercury; phlegm, or water; salt; sulphur, or oil; and earth. By spirit, or mercury, he understood every volatile and odorous substance, though simplicity is far from being a constant attendant on these properties. Water, or phlegm, comprehended in his system, all the aqueous and insipid products, and is liable to the same objection with respect to its pretended simplicity. The word sulphur, or oil, denoted all inflammable and liquid substances, and consequently a great number of bodies more or less compounded, as the fat and essential oils, &c. By salt, he

he indicated every dry substance possessing taste and solubility, qualities that belong to a great number of compounds. Lastly, the word earth was applied in the doctrine of Paracelsus, to the dry, fixed, and insipid residues of operations, all of which are now known to differ exceedingly from each other.

Beccher, a chemist, who has treated his subject in the most philosophical manner, was aware of the objections that might be urged against the doctrine of Paracelsus, and from a conviction of its insufficiency, he took another method of arriving at the elements of bodies. He first distinguished two principles very different from each other, humidity and dryness, water and earth. He divided this last into three species; namely, the vitrifiable, inflammable, and mercurial. Vitrifiable earth, according to him, was that which alone possessed the greatest immutability; but when mixed with some saline earth, was capable of forming the most perfect glass. He likewise attributed to it the property of rendering the combinations into which it entered solid, and little subject to change. The inflammable earth was known by the combustibility of the combinations it enters into. Beccher regarded it as the cause of smell, colour, and volatility. The mercurial earth he supposed to exist in mercury, arsenic, marine acid, &c. &c.; and its peculiar character

character was that of giving a very considerable volatility and specific gravity to the compounds in which it existed. Stahl adopted, and commented on the doctrine of Beccher. He regarded the inflammable earth as fire fixed in bodies, and gave it the name of phlogiston. He could not succeed in demonstrating the existence of mercurial earth, and there has nothing been done to this day, which at all establishes it. Stahl paid the greatest attention to combinations containing earth, water, and especially phlogiston; but he has said nothing concerning air, which Hales, nearly at the same period, proved to be a principal agent in chemical phenomena.

From the time of Beccher and Stahl to the present, no change has been made by chemists in the doctrine of the elements laid down by the ancient philosophers. Like Empedocles, they have acknowledged four elements, and have considered each in two different states. 1. As free, or insulated; in the large masses of air in the atmosphere, fire taken in general, water, and the earth attended to at large. 2. Or as combined; in which kind of inquiry their business has been to obtain the component part by analysis.

Such were nearly the opinions adopted respecting the principles of bodies, from the time of Beccher and Stahl, till the valuable

able discoveries of Priestly and Lavoisier, on fixed air and combination, necessarily introduced new opinions. In fact, if immutability of properties, unity, and simplicity, be the true characters of elements; and if it be admitted that this simplicity no longer exists, when a body is found to be capable of decomposition, it must be remarked: 1. That among the four elements there are at present two, namely, air and water, the principles of which, art has succeeded in decomposing and separating. 2. That the existence of fire, in the sense of the word, as used by philosophers and chemists, taken to be a peculiar fluid always identical, is very far from being proved; and that many reasons, and especially the various modifications of fire, tend to weaken the probability of its being such, as we shall shew in the following chapter. 3. That water itself, which seems to have the most striking characters of simplicity and uniformity of structure, has not resisted the late expedients used by chemists; and that M. Lavoisier has succeeded in decomposing it into several aeriform fluids; a decomposition which had already been in some degree exhibited by the differences of appearance shewn by this pretended element in a variety of circumstances. 4. That elementary earth is a creature of the imagination; since it can be shewn, that there are many earthy substances equally simple and incapable

pable of decomposition, as will be done in the concluding chapter of this first part.

From this general enumeration of facts hereafter to be more fully explained, it follows, that we are not acquainted with any simple or unchangeable substances; that the true principles or first elements of bodies elude our senses and our instruments; that such as are called elements are far from being simple, though they are so denominated on account of their influence in natural phenomena, and their existence in a very great number of products. These assertions agree with the opinions of some of the ancient philosophers, who did not regard the elements as the most simple bodies, but supposed them to be formed of principles of a far greater degree of tenuity and unchangeableness.

These notions concerning those bodies, which have for so many ages enjoyed the title of elements, and to which we deny that prerogative, do not prevent us from considering fire, air, earth, and water, as the most simple, or rather the least compounded of the substances we know. And as we meet with these bodies in the analysis of every natural product, of which they constitute the secondary principle, it will not be improper to consider them as elements under that point of view.

We will finish this detail by explaining
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a kind of nomenclature adopted by certain methodical writers, in distinguishing bodies, according to the order of the principles that enter into their composition.

If two elements or principles are united or combined together, there results a body called a mixt. A number of mixts form a compound. Two compounds united form a surcompound. The combination of surcompounds produces a decompound, and these last, in like manner, generate surdecompounds. It is not easy to give examples of these different kinds of composition, as we can scarcely proceed so far as surcompounds. These distinctions appear, therefore, to be ideal, and of no use. M. Macquer, to whom chemistry is indebted for much of its perspicuity, proposes to change this barbarous and inaccurate nomenclature, and instead of it to substitute the words compound of the first, second, third, &c. order. Or we may adopt the same terms to distinguish chemical principles in the order of analysis by which they are obtained, instead of the order of their composition.

C H A P. V.

Concerning Fire.

THOUGH we neither admit of the word element in the sense usually applied to it, nor entertain the opinion that the four bodies, so called, are the immediate principles of all others, or the most simple in nature; yet we think it necessary to attend to them in the first place, because the history of their properties will be useful in the explanation of those of the other bodies, of which we shall hereafter treat; and in the next, because they cannot be ranged in any order relative to natural history, because they are common to all the kingdoms of nature.

Among the four bodies called elements, no one appears to be more active, nor at the same time more simple, than fire. The most ancient philosophers, and after them philosophers in every age, have given this name to a substance which they supposed to be a fluid extremely moveable and penetrating, formed of particles continually agitated, by them regarded as the principle of fluidity and of motion. When we reflect on this subject, we shall find that these properties could only be attributed by conjecture

jecture to a body placed among the elements, since its existence has never been demonstrated; as that of the three other elementary substances has always been. It is, indeed, natural to think that this name, fire, has in all languages and times, been given to the impression that heated bodies communicate, or make on the senses: and which is synonymous to the term heat, as well as to the light that bodies emit when in combustion. The Chancellor Bacon is one of the first who doubted the existence of fire as a peculiar fluid, and took notice that philosophers in defining it, had always mistaken a property for a separate substance. Boerhaave, whose treatise on fire will always be regarded as a master-piece, was sensible of this difficulty, and in order to render the properties of this pretended element more evident, he examined its effects on bodies wherein it is thought to exist; so that he, like all the philosophers who preceded him, has written a history of heated, luminous, rarified, burning bodies, rather than that of fire itself. This confusion is likely to be always found in natural philosophy; for the properties of fire are necessarily connected with those of the bodies whereon it acts; so far from having it in our power to insulate it, we cannot even form an idea of its separate existence: and notwithstanding the advanced state of chemistry,

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mistry, it has not been found possible to seize and confine this principle, which philosophers seem agreed to call a fluid, and whose effects they explain with sufficient facility, when, led by custom, they regard its existence as well established. These difficulties have caused several chemists, and in particular Macquer, to believe, that fire is nothing else but light, and that heat is a modification of bodies arising from the motion and collision of their particles. This opinion, however, is not generally received. To form an adequate notion of the different theories proposed respecting fire, we must not confine our attention to general positions. The only method of attaining exactness, and to throw light on the immense number of facts that compose the science of chemistry, is to divide the subject, and examine its parts separately. We shall consider, in succession, as so many particular effects of fire, light, heat, rarefaction, phlogiston, the changes produced in bodies by heat, and, lastly, the advantages arising to chemistry from their changes.

§ 1. Concerning Light.

We cannot entertain the same doubt concerning the existence of light, as of fire, because its existence and properties are at present

present well known and established. This substance, emitted from the sun and fixed stars, is the cause in most cases of our perception of other bodies. This matter, reflected in right lines from the surface of bodies, is the cause of the sensation of sight, by producing an image of external objects on the retina of the eye. By the assistance of a darkened chamber, means have been found to examine its peculiar properties separate and distinct from those of the bodies from which it is emitted.

The extreme velocity of light is such, that it passes through the space of 80,000 leagues* in a second, according to the most eminent astronomers. Its motion is rectilinear, and of course divergent from the point which emits it, and the elasticity of the rays, or the re-action of the power that reflects them is so perfect, that the angle of their reflection does not sensibly differ from that of their incidence, as is shewn by writers on catoptrics. When light passes near any substance whatever, it is more or less inflected, and this inflection, proving that it is subject to attraction, is an evidence of its existence.

* Of 25 to the degree, or 167,000 geographical miles. T.

Notwithstanding the velocity of light, it is easily deflected out of its course, as well by the bodies it passes through, as by those it passes near. When its course is oblique from a rare medium into a denser, it is refracted, or suffers a change in its direction like other solid bodies; but Newton * discovered that its refrangibility is towards the perpendicular, instead of being towards the opposite part, as is the case with other bodies. For a more minute detail of the properties of light, reference must be made to books written expressly on the subject of optics.

When light arrives at the earth's surface, and presents to our sight the variety of bodies, which it would otherwise be impossible to discern, we find that the mode of action of those bodies on light is such as to distinguish them into transparent or opaque, and coloured. Transparency is the property of admitting the rays of light to pass easily through any substance, and doubtless arises from the form of the pores. † As this property is found in the heaviest and

* Newton did not discover this. Des Cartes first published the discovery of the constant ratio of the series of incidence and refraction; though it was certainly known before to Willebrord Snellius, and Kepler was very near discovering it. T.

† The minuteness of the particles, and smallness of the pores. See Newton's Optics. T.

hardest bodies, it must follow as a consequence that the tenuity of light is extreme. When thus transmitted, the refractions it undergoes are in proportion to the densities, when the bodies are either stones, salts, or glasses, but is greater when the bodies are of the class of combustibles. Thus yellow amber has a greater refracting power, than a saline crystal of equal density.

It was by an examination of the refractions and reflections of light, that Newton succeeded in decomposing, or rather dissecting this body, and in proving that the different rays, which compose a beam of light, are each capable of exciting the idea of a different colour. Before his time, very little was known respecting the cause of colour. As each kind of ray is differently refrangible as well as reflexible, it is found that a beam of light received on a prism of glass is separated into its various component rays by refraction as it passes through, and being intercepted at some distance by a white plane, or body equally capable of reflecting all, they form a long spectrum, consisting of the colours in the following order, namely, red, orange, yellow, green, blue, indigo, and violet; the red being composed of such rays that have been the least refracted out of their course, and the others being more and more refrangible in their order.

The particles at the surfaces of opaque bodies appear to produce an effect on light resembling

sembling that of the prism.* It is on this property of the particles, that all the variety of colours, which charm the sight, depends. The fact is, that bodies are white, when they reflect or return back all the rays of light that fall on them; and, on the contrary, when all the rays are absorbed, we perceive a defect of light, which we call black, and is in reality the absence of all colour: and again, every beam of white light being composed of a series of the seven primary colours, and of every possible intermediate tinge, all differing in reflexivity, each particular body will appear of the colour it is constructed to reflect, while it absorbs the greater part of the rays of every other colour. Colour, therefore, depends on the nature of the surface of the bodies, as transparency does on their pores, and both depend on the habitudes of bodies with respect to light. Thus, for example, the colour called blue, or red, is produced in bodies by an absorption of all the other rays, except the blue or red, which are reflected back.

These are the chief properties of light considered as emitted from the sun or the fixed stars. But ought we to confine our

* The separation of light into coloured rays, in consequence of its falling on transparent particles of definite magnitude, (and all minute bodies are transparent) has not yet been shewn to be of the same kind, or performed in the same manner, as the separation effected by the prism. T.

inquiries respecting this substance to its free and insulated state. Does it not, like every other body we are acquainted with, obey the laws of affinity in the same manner as it is found to be subject to attraction? This conjecture is rendered more probable, by the consideration that the effects of light do not seem to be confined to its mere re-action on bodies that modify or alter its course. If it be true, that bodies exposed to the contact or impulse of light, experience an alteration or change of nature without any other evident cause, it must follow, that light itself is the agent, and produces its effects by a chemical force, or affinity. Though it has not yet been positively decided, whether their changes arise from the decomposition of light itself, or of the bodies thus altered, or of both together, the facts are too numerous and too striking to be overlooked. We shall content ourselves with mentioning in this place only such as are of the most consequence, and the best established; as it is our intention to treat the subject more fully in our history of each natural body in its order.

Natural philosophers have long been aware of the influence of light on vegetation. It was first observed, that plants growing in the shade are pale, and without colour. Herbs that grow beneath stones are white, soft, aqueous, and of a mild or insipid taste; and gardeners avail themselves of the knowledge
of

of this fact to furnish our tables with white and tender vegetables, by binding up and compressing their leaves together, so as to defend them from the contact of light. The more plants are exposed to the solar rays, the more colour they acquire. Such, therefore, is the origin of those colouring matters, of so much value for their liveliness and body, which many of the eastern nations extract from woods, bark, and roots, and which the utmost industry of the Europeans has not succeeded in imitating.

Colour is not the only property that is obtained by vegetables from the contact of the rays of light. Taste, odour, and combustibility, are likewise derived from the same source. Light contributes greatly to the maturity of fruits and seeds; and is the cause why, under the burning sun of America, vegetables are in general more odoriferous, of a stronger taste, and more abounding with resin. From the same cause it happens, that hot climates seem to be the native country of perfumes, strong smelling fruits, dying woods, and resins of various kinds. Lastly, the action of light is so powerful on the organism of vegetables, as to cause them to pour forth torrents of vital, or pure air, into the atmosphere, while exposed to the sun-shine; whereas, on the contrary, when in the shade they exhale nothing but a noxious fluid, or true aerial acid, similar

similar to that obtained from chalk, and known by the name of fixed air, or acid of chalk. This important discovery due to Dr. Priestley, and more minutely inquired into by M. Ingen-houze, shews in a striking manner the influence of light on vegetation. The effects of light are equally seen in a great number of chemical operations. There is not a substance, which in well closed glass vessels, and exposed to the sun's light, does not experience some alteration from this cause. Among these, the mineral acids, the metallic calces, vegetable powders, and volatile animal oils, are most singularly changed. Metallic calces, in general, especially those of mercury, become of a deeper colour, by exposure to the sun; as may be seen by observing painters colours preserved in powder in the shops.* The mineral acids, by the same treatment, become more volatile and fuming. Metallic salts grow black, and animal oils take an obscure brown. All these changes deserve the greatest attention of chemists, though they have not hitherto been strictly inquired into. Scheele

* It has been remarked, however, that the parts of a room painted with white lead and oil, which are defended from the light by furniture, or by keeping the windows closed, become of a darker colour than the rest; and that the action of light permitted to fall on such obscure parts of the surface, in some measure restores the original colour or whiteness. T.

is the only chemist who has described some of them; and we propose to return again to this subject in the following parts of our work,

§ 2. Concerning heat.*

The difficulties that attend the inquiry concerning heat are much more numerous than

* The importance of the theory of heat in chemical inquiries has induced the translator to give a more strict and less discursive view of the subject than is exhibited in the text.

1. Temperature is the state by which a body possesses the power of exciting the undefinable sensations of heat or coldness.

2. The word heat is used as a term to denote the cause of that state.

It is to be observed, that the words temperature and heat are here taken in the most extended sense. The organs of the human frame are not only imperfect when applied to measure the temperatures of bodies, but likewise exceedingly limited in this as well as in every other case. Temperature is therefore used to denote every degree of heat or coldness, whether within the limits of perception or not, and is appreciated by the observation of its effects on bodies.

Heat, considered as the cause of temperature and of other effects, is subject to variation. It is therefore an object of mathematical inquiry, as possessing quantity, either absolutely, or in the same sense as various attributes, such as ratios or motion, are said to possess it. But it is no part of this inquiry, whether heat be motion or matter. Perspicuity requires that these objects should be separately attended to.

3. Bodies

than those relating to light. It has not yet been proved by any phenomenon, that heat is a self-

3. Bodies in contact, or communicating with each other, do, after a length of time, assume or acquire one common temperature.

4. The time of acquiring the common temperature is different in different bodies. A body, which quickly alters its temperature by communication, is said to be a better conductor of heat than such as alter more slowly.

5. When the temperature of a given solid is increased, there is a certain period at which it becomes fluid, and as the temperature is increased beyond this last point, the fluid takes a rare and elastic form with more or less rapidity, forming vapour. Whether an increase of temperature would convert vapour into a fourth state, namely, that of a permanently elastic fluid, or air, has not been decided; but it is probable.

The temperatures at which different bodies assume the fluid or vaporous states are exceedingly various. Some bodies, as for example, mercury, are not frozen but by extreme cold: others, as rock crystal, cannot be melted, but by the most vehement heat modern chemistry can excite: others again cannot be brought into some of the states; and of these the rule is inferred from analogy, till future experiments may tend to clear up the matter.

6. Universally the effects of an increased temperature are either (1) conversion of the whole body into fluid or vapour; or (2) decomposition, by one or more of the chemical principles of the body being melted or volatilized; or (3) without change of state or composition, an increase of the dimensions, which lasts no longer than while the increased temperature remains.

7. Axiom 1. The quantities of heat in two equal bodies of the same kind and temperature are equal.

8. Theorem 1. The quantities of heat in bodies of the same kind and temperature are as their masses.

9. Theorem 2. Two equal bodies of the same kind, but different temperatures, being brought into contact; the hotter will impart half its surplus of heat to the other.

For

a self-existent, a separate substance; and many eminent philosophers have embraced the opinion

For (by 3) they will acquire a common temperature by contact, and by that means (7), the quantities of heat will be made equal. This can only be effected by the hotter body imparting half its surplus.

10. Theorem 3. Two bodies of the same kind, but different temperatures, being brought into contact; the surplus of heat, by means of which the one exceeded the other in temperature, will be divided between the two bodies in proportion to their masses.

For (3) they will acquire a common temperature, and the whole quantity of heat in each will then (8) be in proportion to its mass. This can only be effected by dividing the surplus in the same proportion.

11. Corollary 1. The quantities of heat required to be added to or taken from bodies of the same kind to bring their temperature to a given standard will be as their masses.

12. Corollary 2. Hence a thermometer, with a very small bulb, may be considered as possessing the temperature of the body it is in contact with, because the common temperature will not sensibly differ therefrom when the body is of considerable magnitude.

13. The mercurial thermometer nearly measures the true increments of temperature.

This is determined by experiment (by De Luc). Let a thermometer be graduated so as to shew the equal increments (6) of the expansion of the mercury; and the common temperature of two equal bodies of the same kind in contact (as for example, measures of water) will be nearly the arithmetic mean between the two original temperatures, as shewn by such an instrument. The instrument therefore gives results nearly agreeing with deductions (9) made from the general phenomena of heat, or it nearly measures the true increments of temperature.

14. Axiom 2. If two equal masses at different temperatures be brought into contact, and the common temperature be either higher or lower than the arithmetical mean (9), the

opinion of Bacon, that it is nothing more than a modification, of which bodies are susceptible.

(9), the surplus of heat, by means whereof the one exceeded the other in temperature will be unequally divided; and the disposition to be heated, or the capacity or affinity for heat, is greater in one body than in the other.

15. Theorem 4. The capacity of equal masses for heat are inversely, as the changes of temperature they undergo, when differently heated and brought into contact. And the contrary.

For the surplus of heat is divided into equal parts by the thermometer: of these parts, the hotter body loses a certain number by communication to the colder, and retains the remainder. The number of degrees lost constitutes the change of temperature in the hotter, and the remainder is the change in the colder. But causes are ever proportional to their effects: therefore the capacities are as the proportions of heat retained by each; that is, inversely as the changes of temperature.

16. Corollary 1. Hence if any given body, as for example, fluid water, be assumed as a standard, the capacities of other bodies being experimentally found, may be ranged numerically, so as to form an useful table.

17. Corollary 2. The quantities of heat required to be added to or taken from bodies of equal mass, to bring their temperature to a given standard, will be as their capacities.

18. Corollary 3. The quantities of heat required to be added to or taken from bodies in general, to bring their temperature to a given standard, will be as their masses (11), and their capacities jointly.

19. Corollary 4. The capacities, in general, will be directly as the quantities of heat so taken, and inversely as the masses; or they will be in the inverse ratio of the changes of temperature, and the masses of two bodies placed in contact. This, in the form of a practical rule, is, multiply the weight of each body by the number of degrees between its original and the common temperature, and the capacities of the bodies for heat will be inversely as the products.

20. Theo-

ceptible. It is certain that philosophers, as well as the common rank of men, have always

20. Theorem 5. The whole quantities of heat contained in bodies of equal mass and temperature are as their capacities.

For if the temperatures of various bodies be supposed gradually and equally to diminish till the absolute privation of heat be obtained, the quantity of heat given out in any portion of the time (17) will be proportional in each body to its capacity. And the whole time being made up of such portions, the respective sums of the quantities of heat given out by each body will be in the same ratio.

It is the business of experiment to determine whether the ratios of the capacities be the same in all temperatures, *cæteris manentibus*.

21. Scholium. From the foregoing theorem, many writers have called a table of capacities by the name of a table of specific heats. These terms, which seem improper, or at least unhappy, because applied to quantities that continually fluctuate, have certainly rendered the theory of heat less easy to beginners.

22. As far as experiments have hitherto been made, it is found that the capacity of a given body for heat is least when solid, greater in the fluid state, and greatest in the vaporous state.

Thus for example, ice and water being exposed in equal quantities to similar heating matters, as before a fire, the ice will be melted without increase of temperature, while the water acquires 162 degrees of Fahrenheit's thermometer. Or equal parts of water at 162, and ice at 32° being mixed, the ice will melt, and the whole, instead of the mean temperature, will remain at 32°. In either case the ice requires 130° of heat, which produces no other effect than rendering it fluid, and is not shewn by the thermometer. So likewise the condensation of steam, though little if at all hotter than boiling water, communicates much more heat to a refrigeratory than the same quantity of water equally hot, and therefore it contained more heat. The quantity of heat which constitutes the difference between the

always supposed heat to indicate the presence of fire, and have sometimes taken it for the element

the several states of the body, has been improperly called latent heat.

23. Problem. The ratio of the capacities of the same body in the solid, and the fluid states, and also the number of degrees the fluid would increase in temperature by the heat which would simply melt the solid, being given; it is required to determine the number of degrees of the same thermometer between the natural zero, or absolute privation of heat, and the temperature of the solid just melting.

The whole quantity of heat in the solid when just melting, will be denoted by the number of degrees of its temperature from the natural zero: and the whole quantity of heat in the fluid will be denoted by the same number added to the number of degrees the temperature of the solid would have been raised by the heat applied to melt it, if its capacity had not been changed by melting. This last number consists of the observed increase of temperature in the fluid augmented in the inverse ratio of the capacities (15). Now the capacities of the solid and fluid being as their whole quantities of heat (20), it will follow that

The difference between the numbers expressing the capacities,

Is to the number expressing the capacity of the solid;

As the difference between their respective quantities of heat, in thermometrical degrees of the solid,

Is to the number of degrees expressing its whole quantity of heat, or its temperature from the natural zero.

This, in the form of a practical rule, is, multiply the number expressing the capacity of the fluid into the number of degrees the fluid would have increased in temperature by heat, sufficient to melt the solid; divide this product by the difference between the numbers expressing the capacities, the quotient will be the number of degrees of temperature from the natural zero.

This problem is Dr. Irwine's, of Glasgow.

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element itself, and on other occasions for one of its characters.

Its

From experiment, it appears, that the natural Zero is 1268 degrees of Fahrenheit's scale below 0 or 1300 degrees below the freezing point of water.

24. Corollary. The difference between the zero of any scale, and the natural zero, being once determined from experiment, it will be easy in all cases, where any two of the three quantities, the capacity of the fluid, the capacity of the solid, and the number of degrees the fluid would be raised by heat sufficient to melt the solid, are given to find the third.

25. The foregoing theory of heat may be applied to explain all the changes of temperature in bodies from the utmost violence of ignition to the most intense cold. For whenever by condensation or freezing, or by a change in the chemical combinations of bodies the capacities are diminished, a part of the heat contained will (15) be applied in raising the temperature. And on the contrary, cold will be produced whenever bodies are melted, or evaporated, or any chemical process goes forward, by which the capacities are increased.

26. The grand question, whether heat be merely a vibration of the parts of bodies, or a peculiar fluid is not decided. If heat be merely vibration, it will be scarcely possible to account for its not being universally communicated to bodies according to their masses, as the established laws of motion require; but if heat be a peculiar fluid, the notion of a greater or less capacity for that fluid, whose variations of density will be the cause of change of temperature, will very naturally account for the different quantities required to be imbibed or given out by bodies of equal weight, before a like density or temperature can be produced in all. Neither will it be at all difficult, according to this hypothesis, to give very probable accounts of what happens when bodies change their states of solidity, fluidity, or vapour.

27. The various theories respecting heat, considered as matter, and a component part of bodies, are not sufficiently grounded

Its leading properties are to penetrate all bodies, to diffuse itself uniformly, so as to tend to an equilibrium, to dilate the several substances it penetrates, and, lastly, to cause them to assume the state of fluidity, and afterwards that of vapour.

Bodies become heated in general in three manners, either by the contact of another heated substance, or by motion, or by the act of combination. Every one must have observed, that in mixing two similar fluids, the one sensibly hot, and the other cold, the former loses part of its heat by communication to the second, and the temperature becomes equal in each; and the same is true of solid bodies that have remained a sufficient time in contact. The developement of heat by means of motion is equally well known. Two hard stones, or pieces of wood, or ivory, or metallic matters strongly rubbed or struck together, produce a degree of heat, that in many cases proceeds even to ignition.

grounded on decisive facts to admit of a cursory discussion in this place, or indeed to be ranked with the established doctrines collected and arranged in this present note, though it must be allowed that several of them do honour to the genius and abilities of their inventors. Dr. Black of Edinburgh, Professor Wilcke of Stockholm, Dr. Irwine of Glasgow, Dr. Crawford of London, are among the leading names of philosophers who invented and illustrated this excellent theory here explained; and it is sincerely to be wished, that some cotemporary writer would settle their respective claims before the lapse of time shall have rendered it difficult. T.

And the production of heat by the act of combination is evidently seen in the union of concentrated acids with water, quick-lime, pure alkalis, metals: and inflammation follows on the mixture of certain fluids, as the nitrous acid and oils.

The laws of the communication of heat between bodies were thought to be analogous to those of motion, till the labours of Messrs. * Wilcke of Stockholm, Irwine of Glasgow, Crawford and Kirwan of London, Lavoisier and De la Place of Paris, shewed that nothing is less known or more difficult to be known than the progression and communication of heat in the systems of bodies of unequal temperature. The very ingenious experiments of these philosophers are not yet sufficiently numerous, and they themselves depend too little on their general results to admit of their being regarded as part of the elements of chemical science. It is, however, very probable that they will lead the way to the establishment of a general theory of heat, applicable to all the phenomena of chemistry, in every one of which it is concerned, either as being absorbed or disengaged.

The most accurate experiments have not yet produced any decisive principles respecting the nature of heat, and chemists, as well as the philosophers in other branches of na-

* Dr. Black of Edinburgh is indubitably the father of the modern doctrine of heat. T.

tural science are divided in their opinions concerning it. Some with Lord Chancellor Bacon, think that heat is nothing else but a modification of which all bodies are susceptible, not existing independent of bodies, but consisting merely in the oscillation of their particles. Such was the opinion of the late Mr. Macquer. This set of philosophers ground their opinion on the following facts: Heat follows motion in all its phenomena, and appears to obey the same laws; it constantly accompanies motion increasing and diminishing in the same proportion. If we except the differences it presents in its communication or passage from one body to another, which do not appear reconcileable with that of motion, the analogy between both is striking in all its other properties. That this hypothesis may be the more readily admitted, it is observed, that bodies even of the greatest density have a great number of cavities or pores, whose dimensions may exceed that of the real matter of which the body in question is composed. These void spaces permit the particles to move with respect to each other, and to oscillate in every direction. These oscillations escape our senses, for the same reason as the parts and powers themselves do, namely, their minuteness. And, lastly, these philosophers take notice that the contrary opinion of heat, being matter, has never been proved either from its being

shewn to have gravity, or from the other properties ascribed to it.

Many other philosophers, and some chemists, on the contrary, believe that heat is a peculiar fluid, existing in bodies, all which it penetrates with greater or less facility. They distinguish this fluid in two states, in combination or at liberty: the former is not sensible to our organs, nor indicated by the thermometer. It is in a state of repose in bodies, constituting one of their principles. It is often disengaged in decompositions, and then passes to the state of heat at liberty, becoming sensible by its action on the thermometer, and on other bodies.* They are of opinion, that there is
always

* There are two opinions concerning the change which temperature bodies undergo when they change their state or their mode of combination: by such changes it is found that heat is either absorbed or given out; or to speak more unexceptionably, the alterations of temperature are either less or greater than would have been inferred from general reasoning. Some philosophers say, that the capacities of the bodies are changed, and therefore require more or less heat to occasion similar mutations of temperature than they did before (see our note on p. 112); others affirm, that the heat which disappears or appears has no relation to the capacity, but is either received in combination, as a principle of bodies, or given out as such. These positions are not matter of opinion, but relate to facts, about which philosophers will acquire more knowledge by experiment than by reasoning. If the natural zero be determined truly by Dr. Irwine's theorem, (note on p. 113) and the capacities of various bodies in their states of solidity and fluidity, be found from direct experiment, the corollary to
that

always a certain quantity of heat at liberty in the atmosphere, and that it is this last, which, being absorbed in many chemical operations, produces the increase of temperature we observe on such occasions. As all bodies that pass from the solid to the fluid state, and from this last into the state of vapour, produce cold in the surrounding bodies, they suspect that there is a great quantity of the matter of heat absorbed by these bodies; and that when, on the contrary, fluid substances become concrete, and produce heat, this last is disengaged from the substance that contained it, and has passed from a state of combination to a state of liberty.

Mr. Scheele, who, as well as Mr. Bergman, is persuaded that heat is a self-existent body, has, with great care, examined the phenomena it presents as a chemical agent, capable of entering into combinations. He has even thought himself justifiable in concluding, from his experiments, that it is composed of pure air, which he calls empyreal air, and phlogiston; and that it differs from

that theorem will give the number of degrees the fluid would be raised by heat that would simply melt the solid. If this deduction should be found in all cases to agree with the facts, the former opinion is true; but if not, there is a portion of heat not accounted for, which, if heat be matter, may probably be a principle of bodies. Fiant experimenta. T.

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light only in the relative quantity of this latter principle. But, however ingenious and true the results of the experimental inquiry he has entered into may be, his inductions concerning the nature and principles of heat, do not seem, in our opinion, to follow naturally, nor prevent our continuing to think that the analysis of heat is not yet accomplished.*

Lastly, Messrs. Lavoisier and De la Place seem to suspect that both hypotheses are true, and take place at the same time, that is to say, that heat consists in the existence of a peculiar fluid, and in the intestine oscillations of the parts of bodies excited by its presence.

Whatever may be the nature of heat, the phenomena it presents in chemical combinations and decompositions, are not the less certain, nor the less deserving our most

* Our remarks on the labours of Mr. Scheele, are not in consequence of any want of esteem and respect for this learned chemist, who stands in the first rank among the improvers of the science. After having reflected and considered, with great attention, his treatise on air and fire, translated by the learned M. de Dieterich, Paris, 1781, we think that the new consequences he has drawn are not warranted by the facts, because he does not seem to have paid attention to the dephlogisticated air, shewn to exist in acids and metallic calces, the presence of which is sufficient to explain all the phenomena which he attributes to the passage of heat, through the vessels, and the decomposition that takes place during this filtration. To understand these phenomena, our chapters on air, combustion, acids, metallic substances, &c. must be read. Note of the author.
careful

careful attention. A great number of facts have established it as a certainty, that this body or modification is unalterable in itself, and is not destroyed or lost. And these have induced Messrs. Lavoisier and De la Place to give the following important principle as an axiom respecting the appearance or disappearance of heat.

“ If in any combination or change of state whatsoever, there be a diminution of free heat, this heat will appear again undiminished when the substances return to their first state; and reciprocally, if in any combination or change of state there be an augmentation of free heat, this new heat will disappear during the return of the substances to their original state.”

In rendering this principle more general, and extending it to all the phenomena of heat, they have used the following mode of expression: “ All variations of heat, whether real or apparent, which are experienced by a system of bodies, in changing their state, will be re-produced in an inverse order, when the system passes again to its first state.”

To measure the quantity of heat absorbed or disengaged in the different chemical phenomena, being an operation which, after what has been said, must evidently appear to be of the highest importance; philosophers have endeavoured to avail themselves of means, by which the defects of thermometers

ters might be supplied. Mr. Wilcke proposed to estimate the quantity of heat from the quantity of snow to be melted by the bodies under examination; and Messrs. Lavoisier and De la Place have contrived a certain and easy method of carrying this proposal into practice. It consists of a vessel surrounded with ice, whose interior part can only be melted by the heat communicated or extricated from the substances inclosed therein; and this heat being determined by the quantity of water * carefully collected, will serve, according to circumstances, to shew either the specific heats of bodies, or the quantity of heat disengaged or even absorbed. The inventors have gone so far as to apply it, with success, in the determination of the heat disengaged in combustion or respiration. The brevity we propose to adhere to in this work, and the long detail it would require to give a proper account of the ingenious instrument contrived by these learned academicians, and the methods of using it, oblige us to refer the reader to their own work. †

* From some attempts made by the ingenious Mr. Wedgwood to avail himself of this instrument, it seems that the capillary attraction of the pounded ice, retaining a portion of the water that should flow out, and some unexplained circumstances, where the vapour raised by bodies, at very high temperatures was found to freeze again, instead of passing out in the form of water, are impediments to its use. See the *Philos. Transactions*. T.

† See the *Memoirs of the Royal Academy of Sciences* for their Memoir, read June 28, 1783.

We

We shall conclude this section, by considering in what cases heat and light resemble each other, and the chief differences that appear to subsist between them. It is not to be concluded, that heat and light are the same thing, because the rays of the sun heat such bodies as they fall on; for there are many cases on the contrary, wherein there is much light without heat, as well as others where the heat is considerable, though no light appears. In fact, the phosphorus, diamond, rotten wood, animal matters in putrefaction, shining insects and worms, the rays of the moon reflected and concentrated by metallic mirrors, or by lenses, present a strong * light without sensible heat, and all natural bodies may be strongly heated without becoming luminous.

The solar rays seem to produce heat merely by their impulse on bodies, and the friction they suffer from such as interrupt their passage. Opake bodies, of a red colour, and particularly when of a black colour, are found to be more quickly and strongly heated than white and polished bodies; an effect doubtless arising from the more numerous de-

* All these and other lights that do not produce heat, are prodigiously weak, when compared with the direct light of the sun. The most concentrated moon-light, in the focus of a mirror, is not more than the 300th part of the intensity of common sun-shine. Heat cannot therefore be expected. See *Traite d'Optique* par Bouguer, quoted by Priestley, in his *Optics*, p. 546. T.

lections the absorbed ray suffers before its motion is destroyed, and perhaps from its combining with such bodies, while white bodies reflect it almost totally.

As to the production of light by a strong and continued heat, as is observed in the combustion of oils, fats, wood, the ignition of metals and stones, it depends on causes that by no means imply an identity between light and heat. When combustible bodies are strongly heated, they produce that flame which supplies the absence of the sun, and produces similar effects. But this light, the product of inflammation, may be contained either in the air, whose presence is necessary for combustion, or in the combustible body, and no fact ascertains that it is heat which is changed into light. The incalcescence of incombustible bodies, in which we cannot admit the presence of combined light, at least not in the same state as in combustible bodies, has been explained in a very ingenious manner by Macquer, in the article Fire, in his valuable dictionary. It arises from the strong vibrations excited in the particles of these bodies by heat. These vibrations dispose the particles in such a manner that their facets being continually agitated have the effect of a number of small mirrors, which reflect, and throw directly to our eyes the light which exists in the
air

air * in the night as well as in the day, and do not produce darkness, but when their directions are not towards the organs of sight.

This comparison of the effects of light and heat, leaves us therefore in the same uncertainty concerning the existence of the latter, and even gives additional force to the hypothesis of Bacon.

We have no certainty respecting heat, but the bare facts. The impressions of pleasure or pain produced on animals, the dilation of all bodies, and the consequent diminution of specific gravity, its constant production by friction and collision, its resemblance to motion, its tendency to equilibrium, its production and disappearance in analyses and combinations; and, lastly, its more or less rapid passage or transition from one body to another; these are the principal phenomena with which it is necessary to be well acquainted, in order to apply heat to the best advantage in chemical operations.

* The author has given Macquer's opinion, with fidelity and conciseness; but the value of that opinion will be found to be very small, when it is considered that it is a necessary condition that his system of little mirrors must be placed without the boundary of the earth's shadow before they can receive or reflect the light which exists in the air, &c. T.

§ III. Concerning Rarefaction.

The most remarkable effect attributed to fire by philosophers, and which is certainly produced by heat, is rarefaction. We have already remarked, that the principal effect of heat is to augment the volume of all bodies, without adding to their weight. This rarefaction seems, at first consideration, to imply the intromission of some substance into the pores of the rarefied body, producing the effect of a wedge, by separating them. But when we reflect, that a body rarefied by heat, has acquired no weight, and that its specific gravity is less than in its ordinary temperature, we become convinced that the pores are simply enlarged, and nothing more.

From the phenomena of the relative motion, by which the parts of bodies are removed from each other by heat, it is clear that this power acts in opposition to that attraction by which they adhere together. We may observe the attraction between bodies in three * different states, perhaps not sufficiently distinguished from each other by philosophers. The first combined with an original impulse retains the planets in their orbits, and may be called planetary attraction. The second, or terrestrial attraction, is the cause of the property we call weight.

* See note on p. 43.

And the third is that by which the parts of bodies adhere together, and have various specific gravities, according to its intensity. It is the attraction which produces aggregation, and which heat tends to destroy; and by diminishing this, it produces a great number of effects, combinations, decompositions, vegetation, animalization, &c.

Boerhaave, who has considered the effects of fire rather as a philosopher than as a chemist, has laid down three rules, or laws, concerning rarefaction considered in general, which we will now proceed to examine.

L A W I.

All Bodies are dilated by Heat. ||

Though it be true in general, that almost every body in nature is dilated and rarefied by heat, it is necessary to make some remarks on this phenomenon. In the first place, all mineral substances without exception, experience a dilatation, which is greater the more intense the heat. This rarefaction is such as to destroy the aggregation of a great number of them. But if

|| This law is universal in bodies so long as they retain the state of solidity, fluidity, or vapour they happen to possess; and have suffered no change either in the combination or quantity of their chemical principles. If the rule be taken in this sense, the exceptions of our author will not stand. T.

this

this law be applied to animal and vegetable matter, it is subject to some exceptions. It is true, that a certain degree of heat dilates their fibres, separating them, and diminishing the density of their structure; but a stronger heat suddenly applied, produces an opposite effect. Every one knows that parchment, vegetable and animal fibres, and wood itself, shrink and contract when quickly heated. We find even in some mineral substances a property contrary to this law. Soft and ductile clays are condensed and hardened by fire, so as to lose much of their dimensions, and at the same time are so hardened, as to strike fire with the steel.

L A W II.

Bodies rarefied by Heat, have all their Dimensions enlarged.

A bar of iron increases both in length and thickness when heated. Philosophers have contrived many instruments to exhibit and measure this effect of rarefaction. The pyrometer invented by Muschenbrock, shews the dilatation of heated metallic bars to the 12,500 of an inch. This sensibility is obtained by the motion of expansion being communicated through several levers, whose arms are of unequal length; so that the extremity of the last is moved through a space sufficiently

sufficiently large to give motion to a wheel, which carries an index or hand round a graduated circular plate, and shews the minutest changes of length in the bar under examination. But as this instrument is used only to shew the expansion of metallic bars lengthwise, philosophers have made an experiment with a cylinder of metal fitted to an orifice in a metallic plate, so as just to pass through it when cold, and they find that the same cylinder, when heated, could not pass. It is, therefore, established, that bodies expand by heat in diameter as well as in length.

This phenomenon is well known to chemists, who find it necessary to leave sufficient room in the iron grates they place in their furnace, which, without that precaution, are found to do injury by their expansion.

L A W III.

The Dilation by Heat is directly as the Rarity, or inversely as the Density of Bodies.

Boerhaave, in the establishment of this law, compared the effect of heat on no more than three solid bodies, and these very different from each other, namely, wood, stone, and metal. He found that the rarefaction of the particles of these bodies followed the inverse

ratio of their density, and from thence drew the general inference. But M. Buffon, in repeating the experiment of the rarefaction of a great variety of solid bodies by heat, found that heat dilates them in proportion to their susceptibility of alteration by fire. That is to say, stones in proportion to their calcinability, and metals in proportion to their fusibility. Boerhaave extended this law to fluids, on no better ground than trials made with air, spirit of wine, and water. If he had brought mercury into the comparison, he would not have generalized his law; for though much more denser than either the spirit or the water, its dilation is greater. This experiment proves, that neither the quickness of becoming heated, nor the degree of expansion, is governed by the inflammability, or by the fusibility of the matter under consideration. Messrs. Bucquet and Lavoisier, who have made a long course of experiments on the dilation of fluids by heat and its progress, have not been able to discover the cause of the singular diversity they have observed, and have contented themselves with describing the facts without drawing any inferences.

In addition to the laws of the rarefaction which heat produces, and which are far from being yet well understood, it is essential to know, 1. That all bodies, in passing from the solid to the fluid state, or from fluidity to vapour, produce cold, as salts by solution

solution in water, ether by evaporation, &c.
2. That fluids, capable of becoming concrete, produce heat in passing to the solid state. Thus water, which freezes by being placed in a freezing mixture, never becomes so cold as spirit of wine plunged in the same mixture: a circumstance, which shews that the water, during its conversion into ice, has given out heat sufficient to diminish the effect of the mixture.

§ 4. Concerning Phlogiston.

Beccher, struck with the wonderful property certain bodies possess of producing fire, that is to say, heat and light, by repeated motion, or by the contact of other bodies in a state of ignition, concluded that it depended on a particular principle, which he called inflammable earth. Stahl, whose attention was strongly fixed on this doctrine, imagined that this principle was pure fire, or the matter of fire fixed in combustible bodies, and gave the name of phlogiston, or the inflammable principle, to this element thus combined; in order to distinguish it from fire in action, or in a state of liberty. Its properties, when in combination, are therefore very different from those it possesses when at liberty; so that it can no longer be known by its two distinguishing criterions, heat and light. But it resumes them when separated from the bodies which confined it, and appears again with all the
I 2 brilliancy

brilliancy and heat which accompany it when set free. Such was the simple and sublime idea of Stahl on the nature of combustible bodies. It is, in fact, natural to think that such matters, as by becoming once strongly heated, take fire, and continue to burn till intirely consumed, owe this property to fire concealed within them; and that combustion is nothing more than a process by which this fire is developed. All inflammable bodies therefore, according to Stahl, contain fixed or combined fire, which is the principle of their inflammability. Hence he regarded the inflammable principle as identical in all bodies that contain it, whatever be their nature, or, however they respectively differ from each other. Nothing more was required than the property of combustibility, to prove the presence of phlogiston in large quantity. Thus sulphur, coal, metals, oils, phosphorus, &c. owe their inflammability to fixed fire, and the differences of structure, form, colour, consistence, weight, &c. depend on the various principles with which the phlogiston is united; this last being universally the same, except when by change of state it becomes free or uncombined.

To arrive at a knowledge of the properties of fixed fire, or phlogiston, Stahl made a comparison between such bodies as contain it, and others into which it does
not

not appear to enter. He observed, that the first in general possess colour, smell, fusibility, volatility, and combustibility; while the latter are usually colourless, without smell, more or less fixed, infusible, and more especially incombustible. He has also taken notice, that bodies, manifestly abounding with phlogiston, lose the greater part of the properties common to them as such, on being deprived of that principle, and have them restored upon being again furnished with phlogiston.

It was more especially from the consideration of experiments made with sulphur and metallic substances, that he established his doctrine with success. Metals, according to him, are compounds of peculiar earths united to phlogiston. When they are calcined, their phlogiston becomes disengaged; in consequence of which they are no longer fusible, ductile, or inflammable. These properties are restored when the earths are again united to phlogiston, by heating them with oils, coal, or any other matter abounding with that principle. Sulphur is composed of the vitriolic acid united to phlogiston. Its combustion disengages and dissipates the latter, the acid only remains. If this acid be treated with coals, oils, or metals, it deprives them of their phlogiston, and again forms sulphur, which is a coloured,
I 3 odorant,

odorant, fusible, volatile, and inflammable substance.

Notwithstanding the elegant perspicuity of this theory, it is easy to point out great objections to which it is liable. If it be true, that the existence of fire, as a peculiar fluid, is not at all proved even in combustible bodies, in the very state of ignition; and if it be true, that they present nothing else to the notice of the observer but heat and light, how can we admit its presence in inflammable substances in more equivocal circumstances? Whenever we speak of fire, it must be in a vague and inaccurate manner, if we do not confine our observations to light or heat. We have seen, that there are no deductions that sufficiently prove the material existence of heat; but every thing, on the contrary, tends to shew, that it is no more than a peculiar modification. Light is, therefore, the only substance, which being supposed to be the matter of fire, can be affirmed to be fixed in combination with bodies. This opinion was proposed by Macquer. This celebrated man, after having long meditated on the nature of fire and phlogiston, concluded that light possessed all the properties, whether it be considered as free and in motion, or as a principle fixed in bodies, and separable by motion or agitation. This theory perfectly agrees with all the phenomena of chemistry.

In

In the explanation of a system admitted in the sciences, it is necessary at the same time to point out its difficulties, and shew its errors. Every system hitherto offered relating to chemistry, has been more exposed to errors than those in any other science, and that of Stahl is far from being without them. We shall here point out the objections which may be made against the doctrine of this great chemist, which has constituted one of the most brilliant epochs of chemistry, though it has now lost a part of its reputation.

The difficulties attending the doctrine of phlogiston may be comprized under three classes. 1. The properties Stahl has attributed to this principle, are not universally found in those bodies which he affirms to contain it. Charcoal, and in particular that of resins, which he regards as being almost pure phlogiston, is possessed neither of smell, volatility, or fusibility. There are even some charcoals which are not very combustible. Diamond, a substance very infusible, fixed, transparent, inodorous, is perhaps the most inflammable substance we know, since it burns totally, and without residue. Spirit of wine, ether, and many essential oils have no colour.

2. It often happens, that bodies in losing their phlogiston acquire the very properties Stahl commonly attributes to its presence,

and which were scarcely observable in the body before. Most metallic bodies, by calcination, acquire a deeper colour, as may be instanced in cobalt, mercury, lead, iron, copper, &c.

3. Stahl, in his great attention to combustible bodies, from the nature of which, he endeavoured to ascertain that of phlogiston, has paid very little regard to the absolute necessity for the presence of air in combination; and seems to have forgotten how essential it is to that process. It is in consequence of this, that he has not foreseen the strongest objection that could be made to his theory; but which, however, was not proposed by any chemist of his time. If combustion be nothing more than the disengagement of phlogiston, it is clearly a decomposition, in which the inflammable body loses one of its principles. But is it possible that a body, by the loss of one of its principles, should become absolutely heavier than before? Yet it is true, that one hundred pounds of lead afford an hundred and ten of minium; and that sulphur, by combustion, affords more than its own weight of vitriolic acid. And in the same manner, sixteen ounces of spirit of wine, by being burned, affords eighteen ounces of pure water, according to the happy discovery of M. Lavoisier.

The force of this objection, added to the difficulty

difficulty of proving the existence of phlogiston, have induced some modern chemists to deny its existence altogether. But on this subject it must be observed, that notwithstanding the immense researches made of late years into the phenomena of combustion, the opinion, which admits the existence of fire as a principle fixed in bodies, has not yet been overthrown; that the theory of Macquer, which regards light as this principle, satisfies all difficulties and objections; and that M. Lavoisier, whose new and exact experiments would be certainly decisive, if any were so, in overthrowing the doctrine of phlogiston, has not yet adopted an opinion on the subject; as is clear from his admitting of fire in a state of combination, though in a very different, and even opposite, sense to that assumed in the doctrine of phlogiston, as will be seen in the following chapter.

Since the attention of chemists has been directed to the necessity of air to combustion, many important discoveries have been made; the principal of which is, that a portion of atmospheric air is absorbed by bodies that burn, and that it is this part of the air, which, becoming fixed or combined, increases the absolute gravity of metals, sulphur, phosphorus, inflammable air, and spirit of wine, after their combustion. And it has likewise been discovered, that this aug-
mentation

mentation corresponds accurately to the weight of the air absorbed, some chemists, at the head of whom Messrs. Lavoisier and Bucquet may be placed, have admitted a new theory, intirely founded on the absorption of air, and wherein no mention is made of phlogiston. This theory is directly opposite to that of Stahl, and is comprehended in the four following principles :

1. The bodies, called phlogisticated by Stahl, are, according to this doctrine, bodies which have a strong tendency to unite with air ; a tendency which in general constitutes combustibility.

2. All the facts or circumstances in which Stahl supposed phlogiston to be disengaged, consist of nothing more than the entering of pure air into combination. Such are combustion, calcination, respiration, the formation of the vitriolic and phosphoric acids by the combustion of sulphur and of phosphorus.

3. Every circumstance, on the contrary, wherein phlogiston enters into combination, according to Stahl, consists of nothing more, in the pneumatic theory, than the disengagement of air. Such are the production of metals effected by the reduction of metallic calces and charcoal, the decomposition of acids by combustible bodies, and in particular those of the vitriolic and nitrous acids by iron, charcoal, &c.

4. Every matter which Stahl supposes to

to be a compound, containing phlogiston, is regarded in this theory as a simple substance, which has a strong affinity with pure air, and endeavours to combine with it whenever they come into contact. So that combustion consists in a precipitation of air on the combustible body; and every operation, in which bodies have been thought to regain phlogiston, is simply either the disengagement of pure air, or its passage from one body to another.

This opinion, adopted by the late M. Bucquet, in his latter courses of lectures, explains the greater part of the phenomena of combustion, calcination, and reduction of metallic calces; but it does not afford adequate reasons for the flame which is produced by bodies in a state of ignition, nor the rapid motion and other changes that attend it. M. Macquer, who must have been well aware of the influence of the modern discoveries on chemical theory, was of opinion that they do not intirely overthrow that of Stahl, and has found means to unite the pneumatic doctrine we have here explained with that of phlogiston. After having shewn that pure light, such as is emitted by the sun, may be regarded as the true matter of fire, and that by admitting it as fixed in bodies, it constitutes the phlogiston of Stahl; he has explained combustion with great perspicuity, and in such a manner, as removes
all

all the difficulties of the subject. According to him, in every instance of combustion, the pure air disengages the light or phlogiston from inflammable bodies, and occupies its place; so that calcination may be regarded as the precipitation of air, and disengagement of light. When, on the contrary, phlogiston is restored to neutral substances, the matter of light serves to disengage in its turn the air fixed in those bodies, by which means they again resume the metallic state. In this theory, which perfectly answers the intention of its author, by uniting the doctrine of Stahl with that of the moderns, Mr. Macquer thinks that phlogiston can unite with bodies even in closed vessels, because light, which he regards as the true phlogiston, passes through glass vessels, as every one knows, and even penetrates metallic or earthen vessels when heated to ignition. This important position is not found in the theory of Stahl, and we shall hereafter be sensible of its influence in the explanation of a great number of phenomena in chemistry.

We may therefore consider the doctrine of phlogiston as no longer difficult. All philosophers are acquainted with the existence and phenomena of light. And we think it even a matter of astonishment, that the ingenious thought of Mr. Macquer did not occur to other chemists; and that Stahl himself

himself did not pay attention to the influence of light in chemical phenomena. The account we have given of the effect of light on vegetables, essential oils, metallic calces, and salts, may be understood as consequences of phlogiston being imparted to those bodies; and this last term proposed by Stahl, and since admitted by every chemist, must be understood as synonymous to fixed or combined light. It is true nevertheless, that Mr. Lavoisier, whose opinion ought to have as great influence in chemical theory as his experiments have power in accelerating its progress, seems to establish a new theory by degrees, concerning which, in this place, we shall say a few words, as far as it relates to the doctrine of phlogiston. He thinks that light, heat, and all the phenomena that appear in combustion, depend more on the air than on the combustible body. That the flame, which appears, is rather the light disengaged from the pure air, than separated from the combustible substance. The decomposition, which, according to Stahl and Macquer, is effected in the inflammable body, he supposes to take place in the pure air, which he regards as a compound of the matter of fire and another principle; and the phlogiston, whose disengagement is the leading circumstance, is, according to his theory, separated from the pure air. We cannot, in this place, speak more largely on this ingenious system, but shall

shall attend more particularly to it in our next chapter on air. It is proper however to observe, that the matter of fire or of heat, which Mr. Lavoisier admits in pure air, whose disengagement is supposed by him to be the cause of the bright flame in combustion, can be nothing else but the phlogiston of Stahl, or the fixed light of Macquer; and that all chemists are of course agreed that it exists.*

§ 5. The Effects of Heat on Bodies considered chemically.

It has been seen, that one of the principal effects of heat, is the rarefaction of bodies, that is to say, the augmentation of their

* Nothing can be a greater indication of the infancy of a science, than a variety of theories equally probable; for their existence shews that some at least (and perhaps many) of the most essential facts are still undiscovered. The doctrine most generally received in Britain is, that inflammable air is either pure phlogiston, or contains phlogiston nearly pure, and that its transitions with respect to pure air, are similar to what the text affirms from Macquer, concerning fixed light. The great increase of temperature in combustion, is accounted for from the consideration of the capacity of pure air for heat, which from experiment is known to be prodigiously great, and consequently its temperature (page 112. note 22.) must be exceedingly raised, when its capacity becomes less in its fixation. Inflammable air and pure air unite in a high temperature, and form water: the heat, which maintained the aerial state being given out, produces ignition. Flame consists of these two kinds of air, in the act of uniting. T.

bulk,

bulk, by increasing the distance between the particles, and a consequent diminution of their specific gravity. This, in the simple, physical, or mechanical idea, we have exhibited in speaking of rarefaction in general; but when this action is more carefully attended to, we find its other consequences are such, that it becomes of essential consequence to understand them.

The first chemical consideration that presents itself, is, that heat, by removing the particles of bodies farther apart, diminishes their aggregation. The force of aggregation and the affinity of composition being always opposed * to each other, as has been shewn in the third chapter, it is easy to conceive that fire or heat singularly favours † combination, by destroying aggregation. This effect has caused fire to be regarded as the principal agent of the chemists, and they have themselves assumed the title of philosophers by fire. We shall see, however, that they avail themselves much less of its assistance than they formerly did.

The action of heat considered under this point of view, as tending to favour combi-

* See note, page 49.

† The simple removal of particles from each other, may favour combination, by enlarging the intervals through which other particles must pass, in obeying the laws of affinity; and there may be many affinities too weak to act without this assistance. T.

nation, seems to be modified in four different manners, according to the nature of the bodies on which it exercises its power.

1. There are bodies which it only dilates, during the time of its continuance, without altering them in any other respect; these are called apyrous: thus it is found that rock crystal, † exposed to the strongest and most powerful heat continued for a long time, suffers no alteration, either in hardness, transparency, or any other property, and comes forth from this trial as dense and as beautiful as ever. There are few substances equally unchangeable by fire.

2. Heat entirely destroys the aggregation of many bodies, causing them to pass from the solid to the fluid state; such bodies are called fusible. There are different degrees of fusibility, from that of platina, which is exceedingly difficult to melt, to that of mercury, which in our climate is always fluid. This fusibility, carried to the extreme, is volatility. A body is volatilized, or rises into the atmosphere, when it passes from the state of liquidity, by a high degree of rarefaction, to that of an elastic fluid. Being then lighter than the atmospheric air, it ascends till condensed by cold. Bodies possessed of this property, are said to be volatile. Those which do not possess it are called fixed. There are many gradations be-

† It has been melted by flame, urged by a stream of dephlogisticated air. T.

tween fixity and volatility. It seems indeed that there are no bodies absolutely fixed, and that they are only relatively so with respect to our fires, but would rise at greater heats than at present we know how to excite. The same observation applies also to fusibility. The cause why rock crystal cannot be fused, is simply, that we cannot excite a sufficient degree of heat. The infusibility and fixity of bodies is therefore merely comparative amongst each other, and with respect to our fires.

This essential property of volatility must be well discriminated from another kind, which is only apparent. The current of heated air, or explosions of flame, may raise bodies in a state of minute division, though not volatile in themselves. Thus the calx of zink is raised by the rapid motion of the flame which is produced in burning that semi-metal.

3. When heat acts on bodies composed of two principles, one of which is volatile, and the other fixed, it separates them by volatilizing the former. These bodies are decomposed without alteration; so that they may be compounded again, and all their properties made to re-appear by uniting them. This separation of constituent parts, is the true analysis. In order that this analysis may take place, it is a necessary condition that the fixed, as well as the volatile

substance be unalterable by the heat applied; for in this case only can the principles be again combined as before. But as it seldom happens, that bodies are composed of two simple principles, or that the heat can be regulated, so as to separate more compounded principles without changing them, it is easy to conceive, that the number of bodies thus acted on by heat, is very small. This is the reason why chemists make less use of fire in their operations than they did formerly. Substances decomposable by fire, without alteration, are certain mineral matters, such as crystallized salts, and solutions of neutral salts.

4. If the bodies exposed to heat be composed of several principles, both fixed and volatile, the volatile principles combine together, as do also the fixed; so that the decompositions afford new products, which cannot form the original compound by reunion. This is the false or complicated analysis; and bodies thus acted on by heat, are said to be decomposable with alteration.

The greatest number of natural substances are of this kind; because they are composed of too great a number of principles to admit of the action of heat, without new combinations taking place, as well as decompositions. Thus we find, by exposing a piece of wood, or other vegetable matter, to the action of heat, the water, the salts, the oils, and

and the principle of smell, which are all volatile, unite together, and constitute a coloured, saline phlegm, of a strong smell, together with brown or red oils, which did not exist in that form in the vegetable; at the same time that the earth, the fixed salts, and the colouring matter combine together, and produce a new substance, called coal. Every part is therefore changed by the action of the heat, and the phenomena announce a false and complicated analysis, whose results would mislead chemists, if they were not aware of its uncertainty and insufficiency. It is certain that art cannot produce again any vegetable substance by mixture of the phlegm, salts, oil and coal obtained by an analysis of this kind, because the principles it affords have suffered very considerable changes. It is unfortunate that the greater number of bodies are subject to this kind of change by heat. Every animal and vegetable substance, and a great quantity of mineral matters, belong to this class; and for that reason chemists have recourse to other methods of examining them, as will be hereafter shewn.

Thus far we have spoken only of a strong heat, such as is commonly applied in the different operations of art; but a low degree of heat, long continued, produces in the operations of nature a great number of phenomena, which the chemist ought to attend

to, and endeavour to understand. The vibrations excited by the presence of heat, in the solid parts of bodies, and the rarefaction and agitation produced in the fluids, keeps up a continual intestine motion, which by degrees changes the structure of the former, and sensibly alters the consistence, colour, taste, and, in a word, the intimate nature of the latter. This is the general idea we may form of the existence and effect of the chemical operations that take place in natural bodies, of the spontaneous decomposition and re-combination of minerals, with the crystallization, solution, and formation of salts that take place in the interior parts of the globe we inhabit. It is to the powerful agency of heat likewise that we must recur, to account for the alterations of which the bodies of vegetables and animals are susceptible, the motion of the sap, the mild fermentation which produces maturation or ripeness in fruits, the formation of oils, of the spiritus recta, or of mucilages and of the colouring principle, the composition of animal fluids, their decomposition, successive changes and putrefaction. All these important phenomena are produced by chemical operations; and the heat diffused over our globe is the governing principle. Our present intention is sufficiently answered, by the transient view we have taken of this common source of motion, life, and death.

We

We have here given a sketch of the subject, and shall endeavour, in the following sheets, to exhibit its parts with precision and accuracy.

§ 6. Concerning Fire, considered as a Chemical Agent, and the Method of applying it to Bodies.

The different changes produced in bodies by heat, are employed by chemists in decomposing or combining bodies. The first circumstance to be attended to, is to have an exact measure of the degrees of heat necessary to effect the changes, of which the matters under examination are susceptible. The degrees of heat are generally considered under two principal divisions; one comprehending those under the temperature of boiling water, and the other such as are above that temperature. The scale of the thermometer serves to distinguish the former; the latter, for the greatest part, can be estimated only from the fusibility of different substances.

Divisions of Heat below the Boiling Water Point.

The first division extends from 45 deg. to 60 deg. of Fahrenheit.* This temperature

* Reaumur's scale is used in the original. T.

favours putrefaction, vegetation, slow evaporation, &c. It is not commonly used in chemistry, because not considerable enough; except in certain macerations made during winter, or for the crystallization of saline mixtures after due evaporation.

The second division extending from about 68 to 80, continues to promote putrefaction. It excites the spirituous fermentation in saccharine liquors, and facilitates evaporation, and the slow crystallization which follows. This is the ordinary heat of temperate climates. It is used for digestions, saline solutions, fermentations, &c.

The third division lies between the 88th and 100th degrees of the thermometer. In this temperature the acid fermentation is best carried on, and plants are successfully dried for practical use. It is used for certain saline solutions, and to promote fermentations.

The fourth division is at, or near, the temperature of about 145 deg. It is called the mean degree of heated water, and is that of the vessels called *balneum mariæ*. It destroys the organization of plants, and volatilizes the lightest parts of plants, especially the spiritus rector. It is used in the distillation of vegetables and animal matters, whose phlegm and principle of smell are intended to be separated.

The

The water temperature of boiling water, or 212 deg. is used in the extraction of essential oil.

Divisions of Heat above Boiling Water.

The first division melts sulphur, burns organized matter, or gives a low red heat to glass vessels.

The second extends from the fusion of the softer metals, such as lead, tin, or bismuth, to that of the softer kinds of glass.

The third division may be considered as including the fusion of metals of a middle consistence, such as zinc, regulus of antimony, silver and gold.

The fourth serves to bake porcelain, and fuses the more refractory metals, such as cobalt, copper, iron, &c.

The last and highest of all is found in the focus of the burning glass. This extreme heat calcines, burns, and vitrifies, in a very short time, all bodies susceptible of such a change.*

Though these divisions above boiling water are determined by phenomena well known

* The effects of heat are greater, when the flame of a candle or lamp is urged by a blow-pipe, than in any furnace, and greater than in the focus of the best burning lens, if dephlogisticated air be used. A large field for experiment is open, by combining the effects of both, namely, the solar focus, and the stream of dephlogisticated air. T.

to chemists, their admeasurement has not the desired precision. An instrument capable of indicating with exactness the degrees employed in these operations, would be an acquisition of great value and importance. We are assured that such an instrument has been constructed in England. It consists of a very acute angled cone, on which a ring of the same matter is occasionally placed. The contraction of the dimensions of the cone by heat, causes the ring to sink to a position nearer the base, according to its intensity. This ingenious instrument is yet unknown in France.†

The heat required in chemical operations, is produced by the combustion of charcoal, or common mineral coal. For this purpose, various furnaces of different forms are constructed, according to the purpose they are intended to answer. Such are the furnace for digestion, for fusion, the reverberat-

† I do not know whether the inventor of this valuable instrument (J. Wedgwood, Esq.) ever thought of the contrivance of the cone; but the method he describes in the Philosophical Transactions for 1782, is certainly much preferable. Small pieces of clay slightly baked, are formed accurately to a standard size. These contract by the heat, and their dimensions are then measured, by suffering them to fall gently between two graduated rulers, inclined to each other in a small angle. The greater the contraction, the farther they go before they stop, and this contraction ascertains the greatest heat the clay has suffered. These instruments are sold by the inventor in Greek-Street, London. T,

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ing furnace, the wind furnace, the cupelling furnace; and it is possible, by a skilful attention to various particulars, to construct a furnace capable of answering the intentions of every kind. On this subject the chemical dictionary of Macquer may be consulted, where the author describes a peculiar and very useful furnace of his own invention: also the chemistry of Beaumé, the Lithogeognesia of Pott, the Journal de Physique of the Abbé Rosur, in which the description of many furnaces, constructed by various chemists, may be found. The flame of oil and spirits of wine is sometimes employed in furnaces adapted to that purpose.

The manner of communicating heat to bodies in the various chemical processes, likewise deserves to be considered. If the combustible matter itself be applied to the substance itself, or the vessel immediately containing it, the operation is said to be performed by a naked fire. If any substance be placed between the fire and the vessel containing the matter under examination, the interposed substance is called a bath. Hence the names *balneum mariæ*, or water bath, sand bath, cinder bath, metallic bath, &c.

The form of the vessels employed in the treatment of bodies by fire, and the different phenomena presented by the matter exposed to

to its action, have occasioned a considerable number of operations to be distinguished by particular names. Such as roasting, calcination, fusion, reduction, vitrification, cupellation, cementation, stratification, rectification, concentration, digestion, infusion, decoction, lixiviation. These operations performed by the assistance of fire, constitute the principal part of the chemical nomenclature, of which we shall proceed to give a short account.

Roasting is a process by which mineral matters are divided, some of their principles being volatilized, and others changed, so as to prepare them for other operations, to which this may be regarded as preliminary. Minerals are subjected to this, in order to separate their sulphur or arsenic, and to render them more pulverable or friable. In the small way this is done in crucibles, or capsules of earth or iron, and generally with access of air. Sometimes it is performed in closed vessels, for which purpose two crucibles are usually luted mouth to mouth.

Calcination is, as it were, a more advanced stage of the process of roasting. Minerals are by this deprived of their water, their salts or their phlogiston calcareous, stones are thus converted into lime, and the metals into calces. The same vessels are employed for this purpose as for roasting.

By

By fusion bodies are made to pass from the solid to the fluid state, in consequence of the application of heat. Salts, sulphur and metals, are the chief bodies subjected to this process. Crucibles of baked clay of various kinds and figures, with metallic cones or ingot moulds, are the instruments chiefly used. These last give the figure to the matter, which after pouring out, is then either a bar, or ingot, or a button.

In reduction or revivification, the calces of metals are restored to their metallic state by the assistance of fire, with charcoal or other inflammable matter.

Vitrification, is the fusion of substances capable of assuming the transparency, hardness, and other properties of glass. Vitri-fiable earths with alkalis, and metallic calces, are the principal matters subjected to this operation.

Cupellation is the purifying of perfect metals by means of an addition of lead. This last, at a due heat, becomes vitrified, and promotes the vitrification and calcination of such imperfect metals as may be in the mixture, so that these last are carried off in the fusible glass which is formed, and the perfect metals are left nearly pure. The name of this operation is taken from the vessels made use of, which are called cupels. These are formed of the earth of bones, which,

156 CEMENTATION. STRATIFICATION.

which, on account of its porosity, easily imbibes the glass of lead.

Certain powders made use of for including particular bodies intended to be changed by their action, in close vessels, subjected to heat, are called cements. Thus it is that iron is cemented with powder of charcoal to convert it into steel; and green glass with plaster or sand, to convert it into a kind of porcelain. Cementation is a process, which, in certain cases, requires a very strong heat.

Stratification is an operation nearly similar to the foregoing: it consists in the arrangement of various solid bodies in a crucible, or other vessel capable of resisting the fire. These are generally in the form of bars or plates, and are blended with pulverable matters, capable of altering their nature. The disposition of these matters in beds or strata, has given rise to the name stratification. In this manner copper or silver are treated with sulphur, in order to effect a combination. This process differs from fusion, calcination, or vitrification, only in the disposition of the matters.

Detonation is peculiar to nitre, and those matters of which it is a component part. It consists in the noise produced by the explosion of these substances when heated, which is greater or less, according to the manner and quantity of the composition, the sudden or gradual application of the heat,

heat, the closeness of the vessels, &c. De-
crepitation differs from detonation in its
noise being much less, and the term is used
only with respect to such salts as burst
asunder by heat, which causes their water of
crystallization to expand, and make its es-
cape. It is particularly observed in sea salt.
Fulmination is a quick and sudden detona-
tion observed in fulminating gold, fulmina-
ting powder, and the combustion of in-
flammable and pure air when partially con-
fined, or gunpowder in the like circum-
stances.

The operation of volatilizing by heat, such
substances as are in a dry, solid, and often
crystalline state, is called sublimation. The
sublimatory vessels are of glazed earthen
ware, or earthen cucurbits, with glass heads,
or pots of earthen ware or porcelain, called
aludels, arranged one above another by the
insertion of perforated necks within each
other. Sulphur, arsenic, cinnabar, and
many mercurial preparations, some vegetable
matters, and in particular, camphire and
flowers of benzoin, are the chief substances
which are raised in sublimation.

Evaporation is the volatilization of a fluid,
effected by heat, in order to diminish the
fluidity and quantity of the residuum, and to
obtain the fixed salts it may hold in
solution. In this way the water of the sea
or salt springs is driven off, and the salt is
left.

left. This operation is made in broad vessels of earth, glass, silver, or other metals, according to the nature of the liquids under examination. Evaporation is performed with access of air, in order that the fluid intended to be driven off may be at liberty to expand and be dissipated, and that this may be effected more quickly by virtue of the dissolvent power of the air on fluids in a state of vapour.

Distillation is an operation nearly of the same nature, but performed in closed vessels. It is intended to separate the volatile from the fixed principles, by means of heat. Distillatory vessels are either alembics or retorts: the former consists of an inferior vessel, called a cucurbit, designed to contain the matter to be examined, and having an upper part fitted to it, called the capital or head. In this last, the vapours are condensed by the contact of the surrounding air, or in other cases by the assistance of cold water surrounding the head, and contained in a vessel, called a refrigeratory. From the lower part of the capital proceeds a tube, called the nose, beak or spout, through which the vapours, after condensation, are, by a proper figure of the capital, made to flow into a vessel called the receiver, which is usually spherical. These receivers have different names according to their figure, being called matrasses, ballons, &c. Retorts are

are a kind of bottle of glass pottery, or metal, the bottom being spherical, and the upper part gradually diminishing into a neck, which is turned on one side. Distillation is distinguished into three kinds, by ascent per ascensum, by descent per descensum, and sideways per latus. These distinctions, which are but futile, seem to have been taken from the form of the vessels. Matter in a state of vapour always tends to rise; but distillation by alembics has been called per ascension, because the capital being immediately about the body, the vapours rise in an obvious manner. The distillation by retorts has been called per latus, because the neck of the retort comes out at the side of the apparatus. As to the distillation per descensum, it is an unskilful and ill-contrived operation, which is no longer used, because its products are for the most part lost, and those which are obtained are in a foul and imperfect state. It was performed by placing some vegetable substance on a cloth extended over the mouth of a glass vessel containing some water; on this was laid a metal dish containing live coals. In this way several odoriferous matters were in the ancient pharmacy, and for perfumer's use, distilled to obtain their essential oil. The product passed through the linen, and was condensed by the water; but the greatest part made its escape between the
cover

160 RECTIFICATION. CONCENTRATION.

cover and the cloth. A distinction relating to the manner of heating bodies intended to be distilled is much more necessary to be made, than those we have been speaking of. The water bath, the vapour bath, the sand bath, the bath of ashes, consist of these substances contained in proper vessels over the fire. In these the distillatory vessels are plunged, and are by that means kept at a more determined and equal heat. The naked fire is also used in distillations, as is also the flame of a lamp, or of spirit of wine.

Rectification is a second distillation, in which substances are purified by their most volatile parts being raised by heat carefully managed. Thus spirit of wine, ether, &c. are rectified by their separation from the less volatile and foreign matter, which altered or debased their properties.

Concentration is the inverse of rectification, as it is intended to deprive fixed fluids of the water which weakens them, and is driven off on account of its greater volatility. This operation is used with certain acids, and particularly the vitriolic and phosphoric, and also with solutions of alkaline and of neutral salts.

Digestion is an operation in which such matters, as are intended to act slowly on each other, are exposed to a slow heat continued for a long time. It is particularly used in the extraction of such parts from vegetables

as

as are soluble in spirit of wine. The ancient chemists held this process in great estimation. Though this confidence seems well founded in consideration of the change which, after strict examination, it is found that most vegetable and animal substances undergo by a too powerful heat, yet it is not carried to that enthusiasm which the alchemists shewed in their pursuits. These men, with more assiduity and labour than their pretended art deserved, made digestions of many years duration, and believed by that means that it would be in their power to work a great number of miracles. Digestion is now confined to the preparing of tinctures, elixirs, cordials, and it is successfully used in the extractions of vegetable or animal principles without alteration. It is likewise used to advantage in several processes with minerals.

Infusion is a process well known. It consists in pouring water of any required degree of temperature on such substances as have a loose texture, as thin bark, wood in shavings or small pieces, leaves, flowers, &c. It is very useful in separating the most soluble parts of these, and is applied in a great number of chemical operations.

Decoction, or continued ebullition with water, is employed to separate such parts of bodies as are only soluble at this degree of heat. It greatly alters vegetable and animal matters, coagulates the lymph, melts

the fats and resins, hardens fibrous parts; and is advantageously used in chemical operations, by such as are acquainted with its effects.

Lixiviation, is the operation of dissolving or extracting, by the help of hot water, the saline matter contained in the ashes of plants, or the residues of distillation, or combustion, or of coals, or natural earths intended to be analyzed. This operation, therefore, nothing more than a solution by the assistance of heat, and does not differ from infusion, except in the particular application of the latter to vegetable and animal matters, while the former is applied to substances that have the properties of minerals.

Such are the different operations performed in chemistry, by the assistance of fire: and as nothing was formerly done without this agent, this science was then no more than an art, and was called Pyrotechnia. At present it is much less used, in consequence of the discovery of more certain methods of analysing natural substances. The action of solvents or menstruums employed without the application of any heat beyond the temperature of the air, is sufficient to effect the most singular changes, and is productive of clear and valuable deductions. This method is pursued with success in the examination of salts, earth, mineral waters, vegetable matters, &c. Heat
is

is now regarded only as an auxiliary agent, by which combinations are forwarded. As it is employed in different degrees, it would be a valuable acquisition, if we knew how to apply it with uniform intensity. A furnace of this kind has long been a desideratum among chemists, and the manipulations of artists have hitherto been the only guide to the chemist, but it is impossible by this means to have the degree of precision so much to be desired. It is said, that a furnace of this kind has been constructed in England.* We have not yet received sufficient information on this subject, to enable us to construct the like; but if it be true, that such a discovery has been made, chemistry will be much improved by its consequences, and we need not doubt its speedy adoption in France.

* I know of none such: but it is probable that the utility of Wedgwood's thermometer in shewing the variations of the higher degrees of heat, and by that means directing the artist to raise or lower his fire by the usual methods, has given rise to this report. T.

C H A P. VI.

Concerning the Air.

THE air is an invisible, inodorous, insipid, elastic, fluid, easily put in motion, capable of rarefaction and condensation, which surrounds our globe to a certain height, and is called the atmosphere. The atmosphere is far from being intirely composed of such air. As it receives all kinds of vapours that rise from the earth, it may be considered as a chaos, whose parts are very difficult to be known. We shall see, however, that this inquiry has been prosecuted with considerable success. Water, mineral exhalations, and the elastic fluids disengaged from various substances, are continually rising into the atmosphere, and constitute, as it were, its different elements. The history of the atmosphere consists of that of its dimensions, which is not yet ascertained with precision; of the changes it experiences in weight; of the density, temperature, and other properties of its several strata; of the effects of its rarefaction and dilatation; of winds, and of meteors. All these objects belong to that part of natural philosophy
which

which is called meteorology, and does not come within our intended limits : but as the air has a singular influence on all chemical phenomena, and it cannot but be of consequence to know in what respects this is exerted, we shall here pay some attention to its physical, as well as its chemical properties.

§ 1. Concerning the Physical Properties of the Air.

We regard the fluidity, its invisibility or extreme transparency, its want of taste or smell, its gravity and its elasticity, as the physical properties of air. Each of these requires to be attended to separately.

The rarity of the air is such, that it easily gives place to the smallest impulse. The rarity and fluidity depend on its peculiar state of aggregation ; and as the same state is found in other substances not of the same nature as the air of the atmosphere, such substances are termed aeriform fluids. It is the distinguishing criterion of this state of aggregation, that bodies possessing it do not assume the solid state by mere cold, as most liquid substances do. The fluidity of the air renders it susceptible of those rapid motions of its parts, which are called winds. It is not, however, of that subtlety, as to pass through the pores of many bodies. Transparent substances, through which light passes

with extreme facility, are not penetrable by air. Water, saline solutions, oils, and spirit of wine pass through a great number of bodies, whose texture is not penetrable by air.* It has not that property by which liquids insinuate themselves into the pores of certain bodies, and cause them to expand.

Air included in vessels is perfectly invisible. It is not at all distinguishable by the eye from a vacuum. The great facility with which it suffers the rays of light to pass through its substance, is the cause of this. It is consequently colourless, though some philosophers have thought its large masses were blue.†

The air has always been supposed to be perfectly insipid. But if we attend to the consequences of this fluid touching any bare nerve of an animal, as is the case in wounds and other similar circumstances, we may conclude that it has a kind of sapidity, which

* This may be true ; but it has never been proved in the most satisfactory manner ; namely by the condenser. T.

† Colourless fluids appear to reflect the light in the order of its reflexivity, and will therefore appear of a different tinge, accordingly as they are viewed by reflected or transmitted light. Thus the air is either red, orange, or yellow, according to its thickness, as is seen by the colour of the clouds illuminated at sun-set by this transmitted light ; the green, blue, indigo, and violet rays being more reflexible, are turned back, and exhibit the sky blue. Water has a similar appearance when in large masses. The sea by reflection is blue, but by transmission is red, as Halley observed in the diving bell. T.

habit has probably rendered insensible. In fact, the exposure of wounds to the air is often attended with very acute pain. The infant, at the instant of its birth, sufficiently shews, by its cries, the disagreeable impression this contact occasions. This kind of acrimony in the air appears to be the cause of that difficulty with which wounds cicatrize, if not kept covered; and a similar effect is observable in vegetables, whose bark is cut away.

The air is perfectly inodorous, and in those cases, in which a sort of fetid smell is perceived, it is easily accounted for, by attention to the foreign bodies interspersed through it, as mists, vapours.‡

The weight of the air is one of the most valuable discoveries in natural philosophy. It was not well established till about the middle of last century, though it is affirmed, that Aristotle knew that || a bladder is heavier when full of air, than when empty. The ancients had no idea of the weight of the air; but attributed all the phenomena arising from that weight to an occult quality

‡ The smell of electricity is often perceived by sedentary people, when they go into the open air. T.

|| It is not easy to conjecture what may have occasioned Boyle's mistake in repeating this experiment. He found the bladder lighter when empty than when blown up. This certainly cannot be; for the air in the bladder acting only by its residual gravity in air (which is nothing) could not cause any preponderance. T.

they called the horror of a vacuum. The impossibility of raising water by the common pump to a greater height than thirty-two feet, engaged certain workmen to consult the famous Galileo, who was greatly surpris'd at the fact. Death, in all probability, prevented his sagacity from discovering the true cause of this, which was reserved for his disciple Torricellius. He was led to it by the following reasoning: The water appeared to him to rise in the sucking pump solely in consequence of an exterior cause, which by pressure obliged it to follow the piston. The action of this cause is evidently limited, as appears by its sustaining a column of no more than 32 feet of water. If, therefore, it were to act on a fluid specifically heavier than water, it ought to raise and sustain to a height inversely as its specific gravity. From these reflections he was induced to take a tube of glass hermetically sealed at one end, and thirty-six inches in length. He filled this with mercury, the closed end being downwards; then closing the extremity with his finger, he raised the other end uppermost, and plunged the unsealed end beneath the surface of a vessel of mercury. Upon removing his finger, he observed the mercurial column to descend, till after several oscillations its upper surface remained at rest at twenty-eight inches above the surface of the mercury in the basin. By
comparing

comparing this height with the height of thirty-two feet, to which water is raised in pumps, he found it corresponded accurately to the inverse ratio of the velocities. For the specific gravity of mercury and water being in round numbers, as 14 to 1, the mercury was found to stand in the vacuum at only one fourteenth of the height of the water. It was not till after much meditation, that he suspected the weight of the air to be the cause of the suspension of water in pumps; and this doctrine was not incontrovertibly established in France, till after the ingenious experiment of Pascal in that kingdom.

This celebrated philosopher imagined, that if water were sustained at the height of thirty-two feet in pumps, and mercury at twenty-eight inches in the Torricellian tube by the sole gravity of the air, the heights of these fluids ought to vary with that gravity; that they ought not, for example, to be the same on the top of a mountain and in a valley, because the length of a column of the atmosphere must be shorter, and consequently its weight less in the former than in the latter case. In pursuance of this idea of Pascal, M. Perrier on the 19th of September, 1648, at the foot and at the summit of the mountain Puits de Dome in Auvergne, made the famous experiment, which has for ever fixed the opinion of philosophers

on

on this subject. The barometer, or Torricellian tube filled with mercury, and fixed to a scale of thirty-four inches, divided into inches and lines, shewed a fall or diminution of the mercurial column equal to four inches, in ascending from the foot of the mountain to its summit, which is five hundred toises higher. It was therefore clear, that a column of air of that length, is equal in weight to four inches of mercury; and subsequent experiments and inquiries concerning the changes of density of the several parts of the column of air, have been attended with such success, that the barometer is now one of the most useful instruments for measuring elevations.

The weight of the air has great influence on a number of physical and chemical phenomena. It compresses all bodies, and opposes their dilatation. It is an obstacle to the evaporation of fluids. The water of the sea is by this cause preserved in its liquid state, without which it would take the vaporous form, as we see in the vacuum of the air pump. The pressure of the air on our bodies preserves the state both of the solids and fluids; and from the want of this due pressure it is, that on the summits of lofty mountains the blood often issues from the pores of the skin, or from the lungs, and occasions hemorrhages.

Lastly, the air is strongly elastic. It is capable

capable of being very much condensed, and suddenly regains its former state when at liberty. A great number of facts prove the truth of this assertion. We shall here mention one or two of the most obvious, and conclusive. If mercury be poured into a tube in the form of the letter U, and closed at one end, the air in the closed end will contract in its dimensions, in proportion as the quantity of mercury by which it is compressed is greater. The foot-ball of children, consisting of a bladder filled with wind, and inclosed in leather, shews the same elasticity by its rebounding when it falls on hard bodies. The fountain by compressed air shews the same thing. This is a vessel half filled with water, and air is strongly compressed into its superior part: the reaction of the air on the water forces it out to a considerable height through a tube. Lastly, the wind gun, whose effects are well known, owes those effects to the same property. It is estimated that air may be compressed into the 128th of its usual volume.

Heat producing a contrary effect to that of compression upon air, serves to shew, that its volume may be exceedingly augmented by the increase of its spring. When a bladder full of air is exposed to the heat of a furnace, the air is dilated so as to burst the bladder with an explosion. This phenomenon is partly

partly the occasion of the bursting of chemical vessels, which often happens where due precautions are not taken to prevent it. The absence of the pressure of the atmosphere, or the total abstraction of the circumambient air from beneath the receiver of an air pump, causes a bladder inclosed therein to burst by the spring of the included air, which then acts without opposition.

From this account of the gravity and the elasticity of the air, it may be readily inferred, that these properties are the leading causes of the numerous atmospherical changes, and the variations in the mercurial column in the barometer. In fact, the inferior strata of the atmosphere must sustain the weight of the air above them, and are therefore in a state of compression, which diminishes with the greater elevation of places: and the continual change of temperature must also greatly affect the gravity of the air by augmenting or diminishing its elasticity. Thus, as we have already noticed, the air is lighter on the tops of mountains than in lower regions; and it is from the consideration of the effects of these and other changes, that the barometrical changes can only be accounted for. M. de Luc has laboured more assiduously and successfully on this important subject, than any other philosopher.*

* The barometrical measurement of elevations has been well treated of both practically and scientifically by Sir George

§ 2. Concerning the Chemical Properties of the Air.

The properties we have described were formerly the only ones known, or treated of by philosophers. But certain chemists, at the head of whom we may place Van Helmont, Boyle, and Hales, having perceived that air, or at least a fluid possessing all its apparent properties, was obtained in the analysis of many natural substances, adopted the opinion that this element combines with, and becomes fixed in bodies. Such is the origin of the term fixed air, which was given to the elastic fluids obtained in chemical operations. The early philosophers supposed these fluids to be air; but the discoveries of Dr. Priestley have shewn, that there are many bodies which have the physical properties of air, though they differ from it essentially in many respects. It is, therefore, necessary to attend to those other properties, in order to distinguish air from other aeriform fluids, which resemble it in elasticity and rarity. These properties are chemical.

On inquiring into the characters of air, we find two which are peculiar to it, and

George Shuckburgh and Colonel Roy in the 77th vol. of the Philosophical Transactions. T.

well

well adapted to distinguish it from other elastic fluids. The one is the property of promoting the combustion or inflammation of bodies susceptible of that process; and the other is that of maintaining the life of animals that respire it. Let us carefully examine these important phenomena.

It is very difficult to give a good definition of combustion. It is a collection of phenomena, which certain bodies exhibit when heated with access of air; the principal of which are the continuance or augmentation of heat, agitation, or intestine motion, the emission of light, flame, and a total change of the matter burned. Great differences may be observed in combustible bodies; some burn briskly with a luminous flame, as oils, wood, resins, bitumens; others burn without sensible flame, as many of the metals, and charcoal, if well made; others again are consumed slowly without sensible ignition, though with heat, as is seen in certain metallic matters. In all these cases the combustion is performed; and the body, thus burned, cannot be again subjected to the same process, and is called either ashes or calx, according to the nature of the substance. The residue of the combustion is almost always heavier than the body itself was before it was burned, as is more particularly seen in such as are fixed in the fire: but such bodies, as contain volatile inflammable matter, burn with

with more rapidity than the former, and leave a residue much less heavy than before. Oils, &c. are of this kind. But this distinction respecting the weight of the residue is only apparent; for the residue in fact is in all cases heavier than the body itself originally was. This important truth is evinced by a proper attention to the entire product of the inflammation. The fixed part of a body is not the whole residue strictly considered, for the volatile parts escape into the air; and in some bodies the whole escapes in this manner. These last would seem to be annihilated, if we were not to bring the volatile parts into our account, which is an absurd position not to be maintained by inference from any phenomena. Thus we find that spirits of wine and ether burn without leaving any residue in the vessels that contained them; but the matter they consisted of is volatilized and dispersed. But if proper means be used to collect the product, it is found that its weight is greater than that of the original fluid. In this manner, M. Lavoisier obtained eighteen ounces of water by burning sixteen ounces of pure and highly rectified spirit of wine under a chimney adapted to the worm-pipe of a still. And the same, no doubt, would happen with oils, resins, &c. So likewise it is not to be concluded that the ashes of wood is the true residue of the combustion. For a part
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of this substance is dissipated in the air; that which is imperfectly burned, constituting soot; while another part escaping into the air is condensed in the form of water, or exists in the form of elastic fluids of various kinds. It may, therefore, be taken for a general truth, that the weight of bodies is increased by combustion.

The explanation of this increase of weight depends entirely on another phenomenon of combustion, which must be more minutely inquired into. Combustion cannot take place without the access of air, and is always carried on in proportion to the quantity and the purity of that fluid. This absolute necessity for the presence of air in combustion, was sufficiently evident to Boyle and Hales; and each of them has proposed his opinion on this subject. Boerhaave thought that the action of air consisted in its being applied to the surface of bodies, and separated the particles successively from each other. This hypothesis does not by any means shew why the same air should not eternally serve to maintain combustion. M. Morveau supposed this last fact to depend on the too great rarefaction the parts of the air suffered by heat, in consequence of which he imagined the combustible body might suffer a compression incompatible with the state of combustion. But this explanation was offered at a time when the true cause
was

was entirely unknown. M. Lavoisier, by his valuable experiments on the calcination of metals in known and determinate quantities of air, has proved the fact observed long ago by the naturalist John Ray, that a portion of the air is absorbed during calcination, that the metal acquires as much weight as the air loses, and that the metallic calx really contains this portion of air, as is shewn by its disengagement when mercury is reduced by the mere application of heat. Other facts have carried him still farther. With Priestley he has observed, that the air which remains after calcination and combustion, cannot be made to serve for new processes of the same kind, but that it extinguishes bodies on fire, suffocates animals, and, in a word, it is no longer air, &c. ; and that the diminution is in proportion to the quantity of air absorbed by the combustible body. On the other hand, the air obtained from metallic calces, is found to be three or four times as pure as that of the atmosphere; since it is not only capable of maintaining combustion, but renders it much more rapid and perfect than ordinary air does; and a given quantity of this air will suffice to the perfect combustion of three or four times the quantity of a like body, which would be consumed in an equal portion of atmospheric air. This singular fluid, which is obtained from mercurial calces, and exists likewise

in the nitrous acid, and in nitre, has been called dephlogisticated air, by its discoverer Dr. Priestley, who supposed it to be a portion of the air of the atmosphere, from which the phlogiston (which according to him always exists in the air) had been taken away and absorbed by the calx of mercury, which is reduced in proportion as this elastic fluid is disengaged by heat. Without inquiring at present into the truth of this theory, we shall take the liberty to observe, that this denomination may well be rejected, because it leads to a large field of discussion; and that the names of pure air, or vital air, may with great propriety be applied to this fluid; because it is the only fluid which serves to maintain combustion or respiration, and because it is, to use an expression of M. Lavoisier, air in a much more eminent degree than air itself.

From the consideration of the absolute necessity of air to maintain combustion and its presence in metallic calces, M. Lavoisier concluded at first that combustion consists in nothing more than the absorption of pure air by the inflammable body. He regarded the air of the atmosphere, abstracting the water and different vapours that float therein, as a compound of two elastic fluids of a very different nature. The one, which is the only and true air, capable of main-
taining

taining combustion, by being precipitated on, and uniting with bodies, is the pure or vital air. It composes from a fourth to a third part of the atmosphere. The other, which is a fluid destructive to animal life, and extinguishes fire, constitutes from two-thirds to three-fourths of the atmosphere, and is called by him atmospheric mephitic. When a combustible body is set on fire in contact with atmospherical air, the portion of vital air becomes fixed in the body, and the combustion continues while this process is going on; but as soon as the whole of the vital air is absorbed, it ceases. The residue, thus deprived of one of its constituent parts, cannot serve to maintain new combustions; but this atmospheric mephitic will regain the properties it had before, if a portion of pure air obtained from a metallic calx, or from nitre, be added in the same quantity as was lost by combustion. This ingenious theory proposed in 1776 and 1777 by M. Lavoisier, seemed to explain all the phenomena of combustion. It clearly accounted for the increase of weight in metallic calcès, and the extinction of combustible bodies in an air already employed in maintaining combustion; but M. Lavoisier has thought it necessary to modify it by the addition of new observations suggested by his numerous experiments. The very bright flame observed when bodies

in combustion are either plunged in vital air, or when it is blown in a stream on the surface of a body already on fire, by the help of an ingenious apparatus that philosopher has contrived for the purpose, induced him to inquire into its cause, and whether it might not be caused by the disengagement of phlogiston in the form of fire at liberty, according to the theory of Stahl. His attention to this inquiry was the more fixed by the consideration that the celebrated Macquer, notwithstanding the new discoveries, had not abandoned the theory of Stahl, but had connected his own theory with that of the father of chemical philosophy. We have shewn, that Macquer maintained the opinion that the fixation of pure air in combustible bodies was performed only in proportion as phlogiston was disengaged; these substances, according to him, being transferred by double affinity.* M. Lavoisier, observing that the luminous appearance of the flame we have spoken of, (and which too clearly evinces the presence of light, or the matter of fire in action, to admit of controversy,) seemed rather to environ or surround the combustible, than to be disengaged from it, adopted the opinion that the matter of fire or heat is separated from the pure or vital air, in proportion as the body burns and absorbs a part of it. He

* See p. 146.

now thinks, (as far as his learned conversation and certain details in his papers in the Memoirs of the Royal Academy of Sciences have given me to understand,) that pure air, as well as every other aeriform fluid, is compounded of a peculiar principle, and the matter of heat or fire, to which last it owes its aerial form; that it is decomposed in combustion, one of its principles, whose nature he does not at present well understand, uniting with the combustible body, and by that means changing its nature and adding to its weight, while the matter of fire is disengaged in the form of light. So that what Stahl attributes to the combustible body, M. Lavoisier ascribes to the pure air; it being this last which burns, if combustion be made to consist in the disengagement of fire. As to the other principle, which, when united to the matter of fire, constitutes pure or vital air, though M. Lavoisier has not yet intirely discovered its nature, yet as it is ascertained that it almost always forms acids by combining with combustible bodies, he has called it the oxygenous, or acidifying principle. It is this which produces the sulphureous, vitriolic, cretaceous, arsenical, phosphoric, &c. acids in the combustion of sulphur, charcoal, regulus of arsenic, phosphorus, &c. it being one and the same substance in all these. It is to be observed, that in this new theory, the pure or vital

air procured from metallic calces was not contained in them completely formed, but is obtained from them, because the acidifying principle combines with the matter of heat or light which passes through the vessels, the calx of mercury, &c. is heated in.

Such is at present (Oct. 1784) the state of the science of chemistry, with regard to the nature of air, and its influence in combustion. We shall not, for our part, take any decisive part in the theories we have explained, but shall adhere to the province of the historian, as in the first edition of our elements. It is enough that we have shewn the absolute necessity of air in combustion, and its concomitant phenomena, whether they arise more immediately from the nature of air, or of the combustible body.

Respiration is a phenomenon very analogous to combustion. Like combustion it decomposes the air: it can only be carried on in proportion to the quantity of pure or vital air which is present, and, when all that air is destroyed, animals perish in the mephitic air which remains. It is a slow combustion, in which the matter of fire, whether it be derived from the pure air according to the opinion of M. Lavoisier, or whether it comes from the animal fluids, as the theory of Macquer would affirm, does not appear under the luminous appearance of flame, but enters, as it should seem, into
a new

a new combination, which produces heat. Moreover, this invifible and infenfible difengagement of the matter of fire in refpiration, refembles thofe flow combuftions unattended with flame, when metals are calcined. The analogy between refpiration and combuftion is evident from heat being produced by the fame means in both. This heat is communicated to the blood in its paffage through the lungs, and is diftributed by communication through the whole animal fystem, fo as to maintain the due degree of heat, which would otherwife be quickly conducted off by the atmofphere, and furlounding bodies. Mefl. Lavoifier, and de la Place, have difcovered a fecond ufe of air in refpiration, namely, to abforb a principle that exhales from the blood, which they call the bafe of fixed air, and which, if fupera-bundant, would be very prejudicial to the vital functions.

The formation of fixed air, or cretaceous acid, which takes place in the pure or vital air breathed by animals inclofed in a proper apparatus, as was done by the two learned academicians above cited, clearly fhews the dangerous confequences that may arife from clofe places too much crouded, as theatres, hospitals, prifons, the internal part of veffels, &c. and the noxious effects, which air vitiated by refpiration produces on per-
sons

sons of delicate constitutions, are no longer to be wondered at.

We see, therefore, that two leading phenomena tend continually to vitiate and decompose the air which surrounds our globe. These are combustion and respiration. This fluid would soon be rendered unfit for the maintenance of these natural processes, if there were not other phenomena capable of restoring vital air to the atmosphere, in the place of that which is continually absorbed and lost. We shall see, in the third part of these elements, that vegetables possess very extended organs, destined by nature to pour forth this vital air into the atmosphere, when the rays of the sun act upon them. Water itself appears to perform the same office, as we shall explain more largely in the following chapter.

C H A P. VII.

Concerning Water.

WATER has always been regarded as an element of great consequence in most natural phenomena, capable of assuming a great number of forms, of entering into numerous combinations, unalterable in itself, and recovering its first state. But the

the researches of M. Lavoisier have shewn, that water, as well as air, is formed of principles of greater simplicity, which may be obtained separate from each other. This important discovery constitutes one of the most brilliant epochas of chemistry. We shall see, in the course of this chapter, the methods used by this celebrated chemist, in his analysis of water; but we must first consider the physical properties of this substance.

§ 1. Concerning the Physical Properties of Water.

Natural philosophers define water to be an insipid, ponderous, transparent, colourless, and highly fluid body, susceptible of the different states of aggregation, from solidity to that of elastic vapour.

It is found in almost every natural body: there are, notwithstanding, many substances with which art cannot unite it, though this is continually done in nature. It is obtained from wood, and the most solid bones. It exists in the hardest and most compact calcareous stones, and forms the greater part of the fluids, and a considerable proportion of the solid parts of animal bodies. These are the facts that have occasioned it to be reckoned among the number of elements.

The naturalist considers water as existing in large masses, and filling the cavities or depressed

depressed places on the surface of the earth. Its natural history comprehends that of the ice, which is eternally existing on the tops of mountains, and in the polar regions, of the seas, lakes, rivers, and brooks, of the clouds, hail, snow, rain, mists, &c. It is distinguished into terrestrial and atmospheric waters, and its motion or transitions become a subject of meteorological inquiry. It successively passes from the surface of the globe into the atmosphere, and from the atmosphere to the mountains, where it is condensed into streams that are the origin of springs and rivers, by which it directs its course to the grand reservoir, the sea. When we attend to the phenomena of this immense body of water, and observe its agitation by winds, its libratory motion or alternate rise and fall on the coasts called the tides, and its currents; when we perceive the effects of these and other motions, by which mountains are gradually formed, harbours in some places destroyed, inundations produced in others, and other coasts again left dry; when we behold islands rising from the bottom of the sea, and others submerged; we cannot but acknowledge that water is one of the most powerful agents in nature. If we transport ourselves in imagination into the vast recesses of the interior parts of the earth, we shall again meet this element acting in silence in the formation of salts and crystals, and depositing them in the

the clefts of the rocks. These great subjects form a part of the natural history of water; but they cannot be properly explained, till the physical and chemical properties of this substance have been treated of.

The most striking property of water is, its quality of assuming the several states of solidity, fluidity, or vapour. Let us consider each of these modifications.

Concerning Water in the State of Ice.

Ice seems to be water in its natural state. For the natural state of a body chemically considered, is that in which it has the strongest possible aggregation. But as water is most abundantly found in the fluid state, this last has been constantly regarded as the natural state of water.

The formation of ice is attended with several concomitant circumstances, which well deserve to be considered.

1. A heat of some degrees is produced in water by the act of freezing, as is always the case when a fluid body becomes solid. A thermometer plunged in water beginning to freeze will indicate some degrees of temperature above the freezing point, though another thermometer placed in open air sufficiently cold to freeze water, will always stand either at the freezing point, or below it. It follows, therefore, that a portion of the heat
which

which was fixed in the liquid water is disengaged when it becomes connected into a solid; and accordingly we find the specific heat of ice inferior to that of water. The same heat is observable in the crystallization of salts.

2. The access of air favours the production of ice. Water in a well closed vessel freezes very slowly; but if the vessel be opened, it freezes much more quickly, and sometimes in the instant of exposure to the contact of the air. This phenomenon is similar to that which happens in the crystallization of salts. Solutions of salts in closed vessels exhibit a sudden crystallization when uncovered.

3. A slight degree of agitation likewise accelerates this formation, in which respect also we find a similitude between this and the crystallization of salts. By agitating certain saline solutions which do not usually afford crystals, it is sometimes found that they are by that means produced. We have often seen this in solutions of nitre, and of calcareous marine salt. These analogies between the formation of ice and of saline crystals, prove that the former is obtained by a true crystallization.

4. Ice seems to have a greater bulk than the water had before it was frozen, and even breaks, by its expansion, the vessels in which it is formed. It is not, however, the water
itself

itself which has acquired a greater volume in this case, but the air which is separated from the water during congelation, is the true cause of the increase of bulk.*

The following are the Properties of Ice.

1. When slowly formed, its crystals have the figure of needles crossing each other at an angle of 60 to 120 degrees, according to the observation of M. Mairan. Sometimes its crystallization takes a determinate and regular form. M. Pelletier, the scholar of D'Arcet, and member of the college of Pharmacy, observed in a piece of fistulous ice, crystals in the form of flat quadrangular prisms terminated at the ends by dihedral pyramids, though with great varieties. If, on the contrary, water in a considerable mass be frozen suddenly, it forms only an irregular solid, in the same manner as it happens when saline liquids are too much evaporated and cooled suddenly.

2. Its consistence is such, that it may be reduced to dust so small as to be driven by the wind. In very cold climates the ice is so hard that it is cut like stones, and has been employed in the construction of edifices.

* The difficult question concerning the expansion of water by freezing, is not yet well resolved. If it depended on the excluded air, it might perhaps be possible, by proper management, to obtain ice more dense than water. T.

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We are assured that even cannons have been bored out of ice, which have been charged with powder, and discharged several times before they melted.

3. Its elasticity is very strong, and much more remarkable than that of fluid water. Every one knows that a ball of ice thrown on a hard surface rebounds in the same manner as other solids.

4. It has a lively taste approaching to causticity. The impression of ice on the sense of feeling is universally known. Physicians employ it as a tonic or discutient matter externally applied.

5. Its specific gravity being less than that of water, it swims on the surface. This phenomenon, as we have already observed, arises from a great quantity of air interposed between its parts. The property of expansion by freezing, is common to many other bodies, such as butter, tallow, wax, &c.

6. Its transparency is less than that of water, in consequence of the bubbles of air which it contains, at least in such masses as are not regularly crystallized. This may be easily seen by an attentive examination of a piece of ice, and if the cavities be opened under water, the air is distinctly seen to issue out in bubbles.

7. It melts at some degrees of temperature above 0° (or 32° of Fahrenheit) in Reaumur's scale, the liquefaction proceeding gradually

gradually from the surface to the internal parts.

8. In its passage from the solid to the fluid state, it produces cold. Modern chemists think it absorbs heat in melting, and that the quantity absorbed is equal to what was before given out on its congelation. All bodies capable of freezing and melting, exhibit the same appearance, though with variations as to the quantity of heat given out or absorbed.

Concerning Water in the Fluid State.

The properties of fluid water are very different from those of ice.

1. It has much less taste than ice; and is commonly said to be insipid. Those who habitually drink water, find differences, which shew that it has a considerable degree of taste.

2. Its elasticity is less, and has been denied in consequence of the experiments of the Academy del Cimento. But the Abbé Mongez has proved, * by an interesting series of experiments, that it is elastic, and even shews that the experiment of those academicians confirm the same, because the metallic spheres continued to exclude drops of

* The compressibility of water was proved long since by John Canton, F. R. S. by experiments made under the receiver of the air pump, for which see the Philosophical Transactions. T.

water after they had been taken from under the press; which could not have happened, if the water had not been diminished as to its dimensions by the compression.

3. Its state of liquid aggregation gives energy to its force of combination. Hence it has been called the grand dissolvent of nature. In fact, it unites with a great number of bodies, and singularly favours their mutual combination.

4. It does not seem to unite with light, which merely passes through it. It is known that this last alters its course in entering into water, so as to pass in a more perpendicular direction than before.

5. Heat dilates it, and converts it into the gaseous state. Its ebullition consists in this passage from the state of liquidity to that of an aeriform fluid. This phenomenon arises from one part of the water having taken the form of an elastic fluid, and becoming insoluble in the remaining liquid. Each bubble rises from the bottom, and breaks at the surface, where it is diffused and dissolved in the air. We have explained the cause of ebullition at large in our *Memoires de Chimie*, published in 1784.

The weight of the atmosphere has a singular influence on the ebullition of water. In proportion as this weight is greater, so much the more does it oppose the tendency in the water to assume the form of vapour.

This

This accounts for the observation of Fahrenheit, that the temperature of water in a state of ebullition is not always the same. If the elevation of the mercury in the barometrical tube be attended to, it will be found that the temperature of boiling water is higher or lower according to that elevation.

This influence of the gravity of the air on ebullition must take place, especially at different heights in the atmosphere. So that water will, in like circumstances, boil more easily, and with a less degree of heat on the mountains than in vallies, or on plains less elevated. All fluids assume the vaporous state very readily at great heights; and for this reason volatile liquids, as spirit of wine, ether, or volatile alkali, lose the greatest part of their strength on high mountains, as has been observed by philosophers, and lately by M. de Lamanon, at the height of more than 1800 toises above the level of the sea. When the weight of the atmosphere is taken off a vessel of water placed in the receiver of an air pump, we observe it to boil with great violence, and become converted into vapour, though at a temperature not exceeding 120 degrees of Fahrenheit.

A third circumstance which influences the ebullition of water, exclusive of heat and the weight of the atmosphere, is the humidity or dryness of the atmosphere. But this

property being intirely chemical, will be attended to in the next paragraph.

6. If water be heated in closed vessels, with an apparatus proper to receive the vapours, these last, when condensed, form distilled water. By this means it is obtained pure, and separate from the saline and earthy matters by which natural waters are almost always contaminated, and which do not rise with the vapour. Chemists, who require very pure water for their experiments, procure it by distillation. They put common water into a cucurbit of copper, lined with tin, to which a head of the same metal with a refrigerator is adapted, and the distilled water is received in very clean glass vessels. It is proper to be observed, that in order to have very pure distilled water, the vessels should be used for no other purpose. The vessels intended to distill quickly, should be made on the new principles, that is to say, the cucurbit and its head should be of a flattened figure, their horizontal being much longer than their vertical diameter. Water obtained by careful distillation thus conducted, is perfectly pure. Chemists formerly made use of snow or rain water; but it is at present well known, that these waters often contain foreign bodies in solution.

Distilled water has a flat or faint taste, and causes a sensation of weight at the stomach; but by being strongly agitated in
contact

contact with air, it acquires a lively taste, and may be drank without inconvenience. Distillation makes no change in pure water, except that of depriving it of the air, which gives it that fresh and lively taste required to make it potable. Boerhaave distilled the same water five hundred times, without observing any change produced in it. Some philosophers have affirmed at different periods that water becomes changed into earth, because at each distillation it leaves a certain quantity of earthy matter at the bottom of the vessel. M. Lavoisier has made experiments respecting this fact. Having weighed the vessels he used in distilling water, as well as the quantity of water and the residue it affords, he has shewn that this earth is nothing but the matter of the vessels gradually corroded by the water. *

Concerning Water in the State of Vapour.

When water is reduced to the state of vapour by the action of fire, it acquires pecu-

* In addition to these observations on fluid water, it may be observed, that its temperature ceases to increase when the evaporation has arrived at a certain degree of rapidity; that this stationary point is higher in proportion to the difficulty the vapours find in making their escape; that if the vapour be prevented altogether from escaping, as is done in the digester of Papin, it will acquire, by the application of heat, a temperature approaching to ignition, and will dissolve or act on earths and other bodies, which in other cases it does not sensibly affect. T.

liar properties, which it had not in its two former states of aggregation.

1. It is perfectly invifible when received in the atmosphere, provided the thermometer ftands higher than 65 degrees, and the air be not already too highly charged with humidity.

2. If, on the contrary, the atmosphere have a temperature below 55 degrees, and be charged with humidity, the vapour of water forms a whitifh cloud, fenfibly opaque; which arifes from the vapour not being abforbed, or diffolved by the humid air.

3. Its dilation is fuch, that by the moft accurate computation, it is found to occupy fourteen hundred times the fpace it poffeffed in the fluid form.*

4. Its elasticity is fuch, as to produce the moft terrible explofions when confined. This power is ufefully employed in mechanics, of which application the engine for raifing water, commonly called the ftream engine, is an admirable inftance, well known both to philofophers and artifts.

5. According to one of the moft conftant laws of the affinity of compofition, it has a ftronger tendency to combination in this ftate, wherein its aggregation is the moft feeble, than in either of the two others. Chemifts have frequent occafion to obferve

* This varies with the temperature. T.

with

with what rapidity water, in the state of vapour, dissolves salts, softens mucilaginous matters, corrodes and calcines metals, &c.

6. It is perfectly dissolved in air. When it is slowly deposited out of the atmosphere, it constitutes dew. This dissolution is performed in the same manner as those of salts in water, as M. Le Roi, physician at Montpellier, has shewn in an excellent dissertation on the elevation and suspension of water in air. *Mélanges de Physique et de Médecine*, Paris, 1771, in octavo.

7. One of the most singular phenomena respecting water in a state of vapour, is the property it possesses of accelerating the combustion of oil when on fire; as is seen in the experiment of the eolipile applied to the enamellers lamp, or to common fires of pit coal or wood, or fats in a state of inflammation, which cannot be extinguished by water. These phenomena induced Boerhaave to conclude that flame is, for the most part, composed of water. We shall presently see that this happy conjecture of Boerhaave, nearly approaches to the modern discoveries on water; as we shall shew that this fluid increases the flame in combustion, in consequence of its being itself decomposed.

8. Lastly, water in the form of vapour is condensed when exposed to a degree of cold some degrees above the freezing point, as is seen in the falling dew. Sometimes

when the cold is beneath the freezing point it is converted into small crystals of ice. Such is the origin of those rarefied incrustations of ice formed on the internal surface of the glass in windows during intense frosts; and the same cause in Siberia, and other very cold climates, converts the moisture of the breath into a kind of snow.

§ 2. Concerning the Chemical Properties of Water.

The great number of combinations into which water is capable of entering, is the cause why natural waters are very far from being pure, and always contain various foreign matters, especially saline substances.

Water may combine with air in two different manners, 1. It may absorb this elastic fluid, and become charged with it while in its liquid state. The existence of air in water has long since been discovered by means of the air pump; for in proportion as the air above the water is exhausted, the escape of bubbles shews that it likewise contained air. By distillation of water in the pneumato-chemical apparatus air is obtained. When water is boiled, the first bubbles are caused by the escape of air, and the lively taste no longer remains; but this last is restored by exposure to the air, or more quickly by agitation therein. 2. The air dissolves water, and renders it elastic and invisible

invisible when it possesses a certain degree of heat; the hotter it is, the more water it will hold in solution. M. le Roi, has examined very minutely into the state of the water in the atmosphere. The ingenious experiments he has made, shew that heated air, apparently dry, when enclosed in a glass vessel, deposits, on cooling, the water it was overcharged with, which appears in drops; that this quantity is different according to the temperature of the air; that it is precipitated during the night, and constitutes a particular kind of dew. He even thinks, there is reason to conclude from these facts, that the variations of the weight of the atmosphere depend in part upon this water, which abounds more or less, as the temperature varies.

Though the order we have adopted seems to require that we should not yet enter into the consideration of saline matters, we must, nevertheless, observe in this place, that water dissolves these matters very readily, and always contains a certain proportion of them. Selenite and calcareous earth, in particular, are substances which communicate disagreeable and often noxious qualities to the waters of wells, brooks, and rivers. The cretaceous acid, clay, iron, and the extracts of vegetables altered by putrefaction, are likewise found in waters. Waters thus vitiated, are very unfit to be used as drink; such as abound with calcareous earth

are called crude or hard water; their taste is flat, and they produce a sense of weight on the stomach; they retard digestion; sometimes they have the effect of purgatives, and the use of them may even be productive of dangerous consequences. It is therefore very necessary to possess the means of knowing them, of determining with what substances they are vitiated, and of extracting those substances where it can conveniently be performed.

Water proper to be drank is distinguished by the following characters: it is very clear and limpid, its transparency being altered by no foreign substance; it has no kind of smell, its taste is lively, fresh, and in a manner penetrating; it boils readily, and without losing its transparency by the separation of any substance; it dissolves soap, so as to form an homogeneous fluid without clouds or lumps; it boils leguminous vegetables without communicating hardness to them. On the addition of the liquids called re-agents, such as oil of tartar, or the nitrous solutions of mercury or silver, it does not sensibly lose its transparency. And, lastly, it passes readily through the stomach and intestines, and promotes digestion. All these good qualities are found in the water of a spring or a river which passes through a sandy soil, is agitated by a constant motion, and is not charged with putrefying vegetable or animal matter. It is a necessary condition,

on, therefore, that no common sewers or drains should pass into it; that its current should not be impeded or rendered slower by obstacles, or by the water being drained off in too great quantities; that the watering of hemp or the washing of clothes in soapy lixiviums should not be performed in it, &c. &c. On the contrary, such waters as stand without motion in subterraneous cavities, which come from a calcareous or gypseous soil, have no real current, abound with plants and insects, have little depth, and rest on a muddy bottom, composed of putrified vegetables, possess properties, altogether the reverse of those we have pointed out as good. Their taste is either flat or nauseous; their smell mouldy or lightly putrid; their colour often green or yellowish, with mucilaginous or fibrous green or brown remains of vegetables floating therein; they redden vegetable blues; become turbid by boiling; form clouds with soap; harden pulse by boiling; afford precipitates more or less abundantly by means of the re-agents; and, lastly, they produce a sense of weight at the stomach, pass with difficulty through the intestines, and impede the action of the digestive powers.

To correct these bad qualities, several methods are employed entirely grounded on chemical or physical considerations.

1. Stagnant waters are set in motion by digging a canal with a proper declivity, where

where the ground will admit of it; agitating them by means of mills, or causing them to pass through the air in the form of jets, cascades, &c. These methods facilitate the evaporation of the noxious air and putrid spiritus rector the water may contain, cause impurities to subside by uniting them into larger masses, and occasion the absorption of a proper quantity of atmospheric air, &c.

2. Marshes and standing waters are to be cured by carrying away the vegetable and animal matters which are susceptible of putrefaction, and prevent the due course of springs, &c.

3. Water is filtered in jars or other apparatus, whose bottoms are covered with fine sand and sponges; these are to be renewed from time to time. The beds of small rivulets are cleared of the mud, and a proper quantity of sand placed instead thereof.

4. These methods purify water, by separating the heterogeneous matters that float therein, but do not deprive it of the saline substances, nor the putrid spiritus rector it may contain. To separate these, it must be boiled and decanted after subsidence, or filtrated through paper, or clear white sand, and exposed to the air in shallow earthen or stone vessels. It may then be used for common drink without danger; for ebullition takes away the disagreeable flavour, and causes a part of the selenite and calcareous earth to precipitate.

precipitate from hard waters. Water for these purposes should be kept boiling for half an hour, or till it has acquired the property of dissolving soap or boiling pulse without rendering them hard.

5. If ebullition be found insufficient to deprive waters of the calcareous earth or selenite, as commonly happens when these matters are in great abundance, a small quantity of salt or oil of tartar must be added in the boiling, or if that be not at hand, wood ashes may be used. These occasion a precipitation, and the water, after decantation and exposure to the air is perfectly wholesome.

6. Substances proper to counteract or prevent the bad effects or noxious qualities of water may be added, such as sugar, honey, meal, barley, wheat, pot herbs, or aromatic vegetables. But these additions do not communicate the lightness and other good qualities of pure water, and, in fact, only substitute one taste for another.

This account of the chemical properties of water does not extend to the consideration of its power as an agent in combinations, into a great number of which it enters; but in many of these it suffers a singular alteration, which has not been till within these few months discovered, (April 1784) and which deserves all the attention of chemists. It has been long known, that water, in certain cases, favours combustion, as in the
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the inflammation of oil, at great fires, &c. and some philosophers have thought it might be concluded from these facts, that water is converted into air. It is to Mr. Lavoisier that we are indebted for a more accurate knowledge of these phenomena of the nature of water. This philosopher having remarked with Mr. De la Place, that when inflammable air is burned with pure air in closed vessels, pure water is produced, (a fact which Mr. Monge observed, with the greatest precision, in the laboratory of The School de Meziere, nearly at the same time with himself) thought it just to conclude, that water was formed in this experiment by the combination of pure and of inflammable air, which he regarded as its constituent principles. This theory of the nature of water, by which M. Lavoisier deprived it at once of its prerogative as a simple body and as an element, met with such opposition, as convinced him that the decomposition of water was a proof necessary to be added to the synthetical examination of that substance. He therefore endeavoured to decompose this fluid, by presenting to it such bodies as might be expected to separate one of its principles. He associated himself with M. Meusnier for the purpose of making these inquiries; and these two philosophers read a Memoir at the Royal Academy of Sciences the 21st of April, 1784; wherein it is proved that water is not a simple substance, but is composed

posed of inflammable air and pure air, which may be easily separated from each other. To obtain them separate, Mr. Lavoisier first made use of the following process: he placed in a small glass vessel, inverted over mercury, a known quantity of very pure distilled water and iron filings. The metal was gradually and slowly calcined, and an elastic inflammable fluid was collected above the mercury; the quantity of water becoming less in proportion, as the two phenomena were produced. After a length of time the iron may be had entirely calcined, and the water totally decomposed; for it is this fluid, which, according to Mr. Lavoisier, affords the air, and calcines the iron. As it is composed of pure air and inflammable air, the iron by degrees attracts and combines with the former, with which it forms a metallic calx, at the same time that it disengages the latter. Such was the first experiment by which this learned chemist decomposed water; but in his experiments with Mr. Meusnier, he employed a much more short and conclusive process. He caused water to pass drop by drop through a gun barrel, placed in a furnace, and kept at a red heat: the water in the state of vapour is decomposed by the contact of the iron; the pure air it contains becomes fixed in the iron, as is proved by the augmentation of its weight, and the singular alteration it undergoes; and the inflammable air set at liberty

liberty, passes swiftly through the gun barrel, and is received in inverted glasses, properly adapted at the other end. By repeating these experiments with all possible accuracy, these philosophers found, that water contains six parts of pure air, and one of inflammable air; that the latter is nearly thirteen times as light, as atmospheric air, and may occupy a space fifteen hundred times greater than it possesses in its aqueous combination.

Water appears to be capable of acting in the same manner on all combustible bodies, and reduces them with different degrees of facility, to the state of burned bodies, affording at the same time inflammable air. In this manner it has been decomposed by zink, charcoal, and oils. The experiment with this last mentioned substance, is made by letting water fall, drop by drop, into boiling oil, in a retort, whose neck is plunged in water beneath the usual pneumated chemical apparatus; but it requires great precaution to avoid the explosions which take place from the water rising* in the neck of the

* This very common and disagreeable accident, attendant on chemical operations, is prevented by Mr. Babington, of Guy's Hospital, by a simple and ingenious contrivance. The part of the apparatus plunged in the water, is made of a considerable diameter, and is immersed to such a depth, that the subsidence of the external surface of the water is sufficient to suffer air to enter, before the internal water has risen so as to reach the body of the vessel. In cases where the

the retort, in consequence of the vacuum formed within during the ebullition. In order to know whether a combustible body, as a metal or charcoal, &c. is capable of decomposing water, nothing more is necessary, than to plunge it red hot into a vessel of water, over which is inverted a glass vessel likewise filled with the same fluid. The inflammable air, which is always disengaged when water is decomposed, will be collected under the glass vessel. This is the cause of the bubbles produced by plunging red hot iron into water, and the inflammable air collected in that case, as has been observed by Messrs. Hassenfrast, Stouttz, and d'Hellancourt, of the Royal Mineralogical School of France. The same disengagement of air, produced by the decomposition of water, takes place when ignited charcoal is plunged therein.

These are the facts lately discovered concerning the nature and composition of water. Messrs. Lavoisier and Meusnier therefore think that this fluid is composed of six parts pure air, and one inflammable air: that iron, charcoal and oils, having a greater affinity with pure air than the last has with inflammable air, seize it, and decompose the

the admission of atmospheric air would do harm, he injects phlogisticated air, when the ascent of the water shews it to be necessary. T.

water

water entirely; the inflammable air escaping in an elastic form: that water is recomposed by burning these two kinds of air together, which, if carefully performed, affords a quantity equal in weight to that of the two fluids made use of: that water is thus produced in a great number of chemical operations; as for example, when spirit of wine or oils are burned under a chimney, adapted to the worm-pipe of a still, whose other extremity is adapted to a recipient, a quantity of water is collected, which is almost always greater than that of the inflammable fluid made use of; which is occasioned by the inflammable air of these liquids combining with the pure air of the atmosphere, by which their combustion is maintained.

These discoveries, and the theory these philosophers have deduced from them, will no doubt constitute one of the most brilliant periods of philosophical science. But as it is of the utmost consequence to examine the results and consequences with all possible care, we think it proper to propose certain doubts, which we submit to the consideration of the learned inquirers, to whom we are indebted for these discoveries.

Mr. Lavoisier, with many other philosophers and modern chemists, maintain that all aeriform fluids owe their elasticity to the matter of fire or heat which is united to them. This must therefore be the case with inflammable
air;

air; and as the decomposition of water, and its change into inflammable air never takes place, but in consequence of its being in contact with inflammable bodies; do not these contribute to the formation of the combustible elastic fluid, since it is as natural to admit the presence of fixed fire or light in them, as it is to refer it to the pure air and other gaseous substances. But this does not at all invalidate the proof that water is a compounded substance. It may not perhaps contain inflammable air, but only one of the principles that enter into the composition of that air. If this conjecture be allowed, it will follow that we are acquainted with no more than one of the constituent parts of water, namely, pure air. We shall see in the history of acids, metals, &c. that our knowledge concerning these bodies is nearly in the same situation. One of their principles seems to be unknown.

However this be determined, it is certain that water is not a simple body, but is capable of decomposition, and that nature in her grand operations doubtless effects this more easily, and by various other processes, as well as those discovered by art. It is by a decomposition of this kind that water tends to purify the atmosphere, by emitting pure air; that large quantities of inflammable air are disengaged from stagnant waters; that the atmosphere is sometimes so highly charged with this last, as to

take fire, and exhibit luminous meteors, when the restoration of the equilibrium of the electric fluid produces the beginning of combustion; and that water contributes to the production of saline matters, in which pure air is always a principle. In a word, this happy discovery of Mr. Lavoisier explains a prodigious number of phenomena relative to water, and its influence in the great works of nature.*

C H A P. VIII.

Concerning Earth in General.

THE ancient philosophers entertained an opinion that there exists one simple substance, the principle of hardness, dryness, weight and fixity in bodies, constituting the base of all solid bodies, to which they gave the name of earth. This opinion, founded purely on abstract philosophical notions, has been constantly taught in the schools, and is still admitted by some of the learned. Paracelsus, as we have seen, denominated all the residues of analyses, earth; but chemists, by the advice and example of Glauber, having examined those residues, found they were far from being pure earth substances.

* Minutes of the history of the discoveries relating to the composition of water, and of the state of our knowledge respecting that fluid are given in the translator's preface. T.

Boerhaave

Boerhaave, who with some limitation had adopted the opinion of Paracelsus, observed, that after all analyses, there remained a dry, insipid, heavy, colourless matter, possessing all the properties of an earth. But when the proper methods of chemical examination are applied to these matters, it is found that they differ greatly from each other, and that one and the same denomination cannot with propriety be applied to them all.

Beccher admitted three kinds of earth, as has been mentioned, in speaking of principles, namely, the vitrifiable, the inflammable, and the mercurial earth. Stahl regarded the first of these as the true earthy principle, and Macquer joins him in thinking, that the vitrifiable earth ought to be considered as the most pure and simple.

To arrive at a proper determination on this subject, let us consider what are the properties which chemists universally admit, as distinguishing the element of earth. We find six, namely, weight, hardness, insipidity, fixity, infusibility, and immutability. But all these properties are found in the earth of quartz, rock crystal, and vitrifiable stones in general, as well as in that of clays. If therefore several matters, very different from each other, have all the properties attributed in general to the element called earth, ought we to regard them as so many simple and primitive earths, or ought we to adopt the
O 2 opinion

opinion of Stahl and Macquer, who observing the properties of earth most evidently in the vitrifiable, have thought proper to esteem it as the primitive earth, and the others as modifications produced by its entering into different compounds?

Seducing as this hypothesis may be, and however great the confidence we might place in the opinion of such eminent chemists, we cannot think it proper to reckon the vitrifiable earth the primitive base of the others.

1. Because this earth is not entirely the same nature in all the stones wherein Stahl and Macquer admit its existence. 2. Because, without having passed the organs of animals, it may be altered by saline mineral matters, such as alkalis; so that it cannot again, by any method whatever, be restored to its former state of purity: a character, which certainly ought not to be found in an element, whose nature is unchangeable. 3. Because we do not find this earth pure, and possessing all its properties in any organized bodies; in which, nevertheless, we find water essential to their composition. 4. Because we find in several substances all the properties of earthy matters, in the same manner as in vitrifiable earth, though not so intense. 5. Because it is not at all proved, that vitrifiable earth is the base of other earths and solid matters, as some chemists seem to think.

Nature presents several substances to our observation,

observation, which have all the properties of earths. We cannot ascertain which is the simplest among them, because they all seem to be equally so, as far as experiments have determined; and even if it were discovered that one of them were simpler than the rest, it could not be concluded to be the elementary earth, till it was shewn to be the basis of other earths, and the cause of cohesion and solidity in various compounds. We ought therefore, without deciding which is properly speaking the element, to admit of different kinds of earths, and endeavour to obtain such a knowledge of their properties, as will serve to distinguish them whenever they are met with in chemical analyses.

Chemists have long admitted several kinds of earthy matters: but their first divisions were vicious in many respects, because the characters they were founded on were neither sufficiently certain, nor numerous. Such, for example, is the distinction of earths into mineral, vegetable, and animal earths. For, though it is true, that the last fixed residues of vegetables, after lixiviation, are for the most part without smell, taste, or solubility, these properties are not sufficient to justify the classing them with earths, because they are neither unalterable, infusible, nor simple. The substance which forms the dry and infusible base of the bones of animals, and is still called by the name of
O 3 earth,

earth, from its insipidity and insolubility, has been known for some years to be a true saline substance, as we shall shew in our history of the animal kingdom; and it may with great probability be conjectured, that the insipid and insoluble residues, after the last analysis of other animal matters, are of the same nature as the residual matter of bones. The name of metallic earth given to the dry calces of the several matters from the insipidity and insolubility of some of them, does not agree with their other properties; for they are in general fusible, and are all known to be compounded, as will hereafter be shewn.

Mineralogists, who have treated of the history of earths, have paid a greater attention to accuracy and precision in their classification than chemists; who have attended to them only in such a general way as they thought might serve to advance the theory of the science they cultivated. The greatest number of modern naturalists, who have classed these matters, have adopted characters founded on these chemical properties, and by that means given much perspicuity to the natural history of the mineral kingdom. Such are Mess. Wallerius, Cronstedt, and Monnet, who have composed complete systems of mineralogy on this principle. No chemist has made a greater number of researches into the nature of stones and earths than Pott, who
has

has given a methodical arrangement of these bodies, founded on the results of his own experiments. Much praise and gratitude is due from the public to M. Dietrich for his continued labours, and to Mess. Bergman and Bayen for their analyses of many earthy substances. We shall not attempt to exhibit or compare the different systems of these authors, as it is not our present intention to write the natural history of earthy substances, but shall only avail ourselves of their labours to determine how many different kinds of earths there are, chemically considered, and what are the distinctive characters of each.

Before we enter on this subject, we must observe, that it is proper to consider stones and earths as constituting the same class, because they are, in fact, nothing more than one and the same substance in a different state of aggregation. Grit-stone, for example, is nothing more than sand united by the force of aggregation; and sand consists of grit-stone, whose integrant parts are disunited: both substances having precisely the same chemical properties.

M. Pott has divided earths and stones into four classes, the vitrifiable, the argillaceous, the calcareous, and the gypseous. Subsequent discoveries have shewn, that the substances formerly distinguished by the name of calcareous earth, are true neutral salts, and gypseous stones are also known to be

saline substances. Among the four classes of stones admitted by Pott, there are only two which belong really to this genus.

Doctor Black, whose name distinguishes one of the greatest periods of the improvement of chemistry, having examined with much care, the base of the Epsom salt, has proved that it consists of a peculiar substance, which he called magnesia, and placed among the earths. All the chemists have assented to his discovery.

M. Bergman has discovered in the marmor metallicum, or heavy spar, a peculiar earth, which he has called terra ponderosa, or ponderous earth.

We think, we ought to distinguish these two substances, from earths properly so called, in consequence of reasons which we shall give in the following chapters.

From various considerations we think, that no bodies should be admitted as true earths, but such as are perfectly insipid, insoluble, and infusible; and that we ought to distinguish such as possess these properties by the chemical phenomena they exhibit. We therefore admit of but two kinds of pure earths, which are equally simple and elementary.

The first is, that which constitutes rock crystal, quartz, grit-stone, flints, and all hard stones that strike fire with steel. Its chemical character is, that it is inalterable
by

by the strongest fire, neither losing its hardness, transparency, nor other properties by any heat that art can produce.* We call it vitrifiable earth, because it is the only earth which forms a transparent glass by combination with alkalis.

The second kind of earth, which we regard as simple and pure, is the argillaceous. In its state of purity, it presents the following characters. It is almost always opaque, or at least its transparency is never like of the vitrifiable stones. It is always disposed in thin plates, or laminæ on each other. Though it has no more taste than vitrifiable earth, it seems nevertheless to have a kind of action on our organs, as appears by its adhesion to the tongue. Its force of aggregation is never so considerable, as that of vitrifiable earth; whence it follows, that argillaceous stones are never very hard, but break by the blow of a steel instrument, without scratching it, or giving fire, as vitrifiable earths do. This small force of aggregation renders this earth much more disposed to combination, and therefore we meet with pure clay much more seldom than pure crystal or quartz. It may be readily conceived, after this obser-

* F. L. Eshermann, in a treatise on the art of melting, by the assistance of dephlogisticated air, printed at Strassburgh, July, 1786; affirms that he melted rock crystal in one minute into a semi-transparent ball full of bubbles, by flame urged by a fine stream of dephlogisticated air. T.
vation,

vation, why clays are almost always coloured, and why there are few clays which possess the argillaceous characters in an eminent degree. Clay exposed to the action of heat, experiences an alteration which vitrifiable earths do not. Instead of remaining unchanged, it hardens, and obtains an aggregation stronger than in its natural state. It even approaches the vitrifiable earth in hardness and want of disposition to combine, after such treatment. Water has some action on clay, which it penetrates, and renders soft and ductile. That this is a kind of combination is evinced by the adhesion of these two substances, which is such, that they cannot be separated but by the action of a strong heat continued for a long time. The property of clay to be softened by water, and become hard by fire, is of great value in the arts. Lastly, the property of entering into combination with a great number of substances, especially distinguishes it from the vitrifiable earth. From this it is, that clay is found in a great number of compounds; and from the consideration of this, we have spoken more largely of this earth; as a knowledge of its leading characters is necessary, in order to distinguish it in chemical operations.

These two earths we have thought fit to distinguish, as they both possess the characters of elementary substances, and no chemist

mist has yet succeeded in decomposing them. We are not sufficiently advanced in our knowledge concerning the origin, formation, or even the chemical properties of these earths, to pronounce with certain chemists, that the one is more simple than the other, and that the latter is only a modification of the former. We cannot admit, that the earth of rock crystal is the base of clay, which as far as is yet known is not the same substance, either attenuated, divided, or elaborated; for no chemist has ever converted the one into the other.

It rarely happens, that vitrifiable or argillaceous earth is found in nature in a state of purity. The former alone enjoys this privilege in rock crystal; doubtless because, as we have observed, of its great hardness and force of aggregation. Even this is often coloured by foreign matters. It is still more frequently altered and combined with colouring matters in quartz. Argillaceous earth is yet less frequently found alone. The greatest part of the earths and stones, to which naturalists have given different names, are composed of one or the other, or both these earths; or of saline substances, especially lime, and magnesia, with metallic matters, most frequently iron. To obtain a conviction of this truth, nothing more is necessary than to cast an eye over M. Monnet's work, in which that chemist ranges stones

stones after their constituent parts. An attempt worthy of great praise, but which, while it shews the great advantages lithology may expect to receive from chemistry, affords at the same time a prospect of the difficulties that still attend the accurate classification of stones, from their chemical properties. The following chapter will be more particularly employed on this subject.

PART II.

P A R T II.

Concerning the Mineral Kingdom;
or Mineralogy.

S E C T I O N I.Earths and Stones.

C H A P. I.

General Facts and Observations on Mineralogy; the Division of Minerals in general, and of Earths and Stones in particular; their different Characters.

THE design of natural history consists in the knowledge of the bodies which constitute our globe. The whole is full of grandeur and sublimity; and its parts are immense. This science comprehends all terrestrial

terrestrial phenomena, from the meteoric changes of the atmosphere, to the mutations to which the interior parts of the globe are subject. The surface of the earth, its seas, lakes, rivers, mountains, valleys, plains, and caverns; the animated and organized beings which dwell therein, and the inanimate matter of which they are composed, occupy by turns the attention of the natural historian. The man of genius is alone capable of viewing the great design at once in all its component parts; the scrupulous and indefatigable observer attaches himself to the detail. The separate consideration of the parts has produced the various branches of this study. These are inexhaustible. Laborious men have consecrated their lives to the observations and descriptions of the habits and manners of certain insects, and have left the subject sufficiently replete with matter for the gratification of future inquirers.

The study of natural history would, therefore, be discouraging, on account of the immensity of the prospect, if the difficulties were not removed by arrangements, by which the memory is relieved, and assisted. These arrangements are called methods. They consist in such a disposition of natural bodies, as places those nearest each other, which have similar properties; and others remoter, as their properties differ. The classification thus made, ought to be founded on characters

ters which are constant, obvious, and easy to be known.

The division of bodies into three grand orders, called kingdoms, namely, the mineral, the vegetable, and the animal kingdoms, is founded on the most striking differences of character. Though the two last resemble each other in some of their leading properties, yet they are sufficiently different from each other in their external form and organization, to be considered separately.

Minerals form the mass of the globe, or rather the external crust, as far as the labours of men have penetrated. They do not increase in volume, but by juxta position of parts, and the force of attraction. They are subject to no alteration, but such as arises from the chemical action of substances on each other. They are called inorganized, or inanimate bodies.

Vegetables, on the contrary, grow larger by an internal force or principle. They have organs which elaborate the juices they attract from the earth, and from the air. They are subject to the modifications of living substances. They grow, live, and die. They produce their like by a true generation.

Lastly, animals have more complicated organs than vegetables; their changes are more rapid; and they are much more subjected to the action of surrounding bodies, in proportion

tion to their loco-mobility, and their higher degree of sensibility.

That part of natural history which relates to minerals, is called mineralogy. The early naturalists divided minerals into a great number of classes. In their methodical enumeration, they admitted earths, sands, soft stones, hard stones, precious stones, figured stones, salts, sulphurs, pyrites, minerals, metals, &c. Those who are desirous of observing the successive progress of mineralogy, from the time of Henckel, one of the first who has treated methodically on this subject, to that of Daubenton, whose classification is a master-piece of precision and exactness, may see the systems in successive order collected in the Introduction to the *Manuel de Mineralogiste* of Mongez, published in 1784, at Paris. The successive periods of this science are marked by the labours of Bromel, Cramer, Henckel, Wolterstдорff, Gellert, Cartheuser, Justi, Lehman, Wallerius, Linneus, Vogel, Scopoli, Romé de Lille, Cronstedt, De Borne, Monnet, Bergman, Sage; and lastly, Daubenton, who in the present state of the science has left scarcely any thing to be desired.

To obtain a knowledge of the great number of minerals which compose the globe, they must be arranged in several classes, distinguished by very evident characters. We shall, therefore, divide them into three sections.

tions. Under the first we shall range earths, and stones, which have no taste, and do not burn when heated with contact of air; under the second, saline matters, having more or less taste, which melt in water, and do not burn; and under the third, combustible substances, not soluble in water, and exhibiting a flame more or less evident when exposed to the fire with access of air.

Earths and stones form the greatest part of our globe, and are easily distinguished from salts or inflammable bodies, by their insolubility and unchangeableness in the fire. Their arrangement in beds, or successive strata, constitutes mountains or hills, and plains. In the former, they are either in shapeless masses, or in strata inclined to the horizon. In the plains they are horizontally disposed, and covered with a bed of mold fit for the vegetation of plants, which is produced by the decomposition of the organized bodies that are formed and decay on the surface of the earth. The several kinds of earth are frequently distributed in a regular crystalline form in the cliffs or subterraneous cavities. Water, which appears to have formed the greatest part of these, continually attenuates them, transporting them from one place to another, and in general producing in them many changes. Their natural history is divided into geology and lithology; the former treats of earths, the

latter of stones. But these two, as we have before observed, ought to be ranged in the same class; because earths, if we except the soil formed by the residue of decayed organized matters, are nothing else but stones, whose aggregation is destroyed, and stones are formed by the union of earths.

The number of different forms of earths and stones being very great, and the knowledge of them of great importance to science, as well as to the common applications of them to useful purposes, naturalists have in all ages been induced to endeavour to distinguish them by sure and easy methods. The ancients had not the idea of classing them from their distinctive characters, but contented themselves with describing their general properties, and the history of the uses they were applied to, together with their value, or the degree of estimation they were then held in. From this it is that the greatest part of the stones described by Pliny, are not to be found or known. Modern naturalists, aware of the inconveniencies of this method of describing stones, have taken another method of distinguishing them, with the intention that all future ages may understand their descriptions. It is from the external and sensible properties of these substances, that they have distinguished them into orders, gener, and species, and have by that means

means rendered the study of them more easy and advantageous.

The external and sensible characters which distinguish earths and stones in the modern lithological methods, consist in their form, their hardness, their internal structure, or their appearance when broken, and their colour. Several naturalists have added to these some of their chemical characters, more especially their habitudes in the fire, and with acids. We shall here consider each of these properties, that the application of the general principles to the particular history of each genus of stones may be better understood.

§ 1. Concerning the Form or Figure of Stones, considered as one of their general Characters.

By the form of stones, is understood the respective arrangement of their surfaces, with relation to each other. The most transient view of a collection of stones in a cabinet of natural history, shews that some possess a regular geometrical figure, while others are altogether without any symmetry as to their form; and that this regularity is in some cases found in transparent, and in others in opaque bodies. Observation has demonstrated, that some kinds of stones affect a peculiar form in their crystals, and that other kinds

are never found but in mis-shapen fragments. Many naturalists are of opinion that all stony matters have the property of taking a crytallized form, which is more remarkable in some than in others ; but that all have their peculiar forms, which are sensible even in their smallest parts. This is the opinion of Romé de Lille, who has written a very copious and exact history of all mineral substances relative to their several crytallizations *. This philosopher distinguishes the form, which stones and all other minerals affect, under three denominations of determinate, indeterminate, and confused crytallization, and observes, that there is no mineral substance, which does not come under one of these three classes. The truth is, that as many of these affect the second and third kind of crytallization, which are irregular, and not easy to be distinguished, we cannot avail ourselves much of the crytalline form of stones to give them positive and determinate characters from this circumstance. Many mineralogists have, nevertheless, established entire systems of lithology and mineralogy on the regular external forms of the matter described. Linneus is the first who adopted this plan, and though he has not entirely accomplished the inten-

* *Cristallographie, ou Description des formes propres à tous les Corps du Règne minéral, &c.* Paris, 1783. 4 tom. 8vo.

tion meant to be answered in his methodical divisions, he at least directed the attention of observers to the forms of crystals, and opened the way to all the discoveries since made respecting them.

Such is the present state of opinions relative to the influence of crystallography on the study of stones and minerals. It is very useful to lead us to the history of the formation of these substances, and may, in some cases, throw great light on inquiries respecting their nature. It may even serve to distinguish them from each other; but it is not sufficient to serve as the basis of an entire system of mineralogy, because it is in reality nothing more than one of the several means, by the union of which such a system may be constructed. M. Romé de Lille, who has so greatly distinguished himself by his researches into the forms proper to all minerals, has not availed himself of this alone in his classification of bodies, but has only examined and described those minerals arranged according to their respective saline, stony or metallic nature, and their mutual combinations.

§ 2. Concerning Hardness, considered as a Character of Stones.

The aggregation of the parts which compose stones is so various, that lithologists

have advantageously made use of it to distinguish them from each other. Some have an aggregation so strong, and are consequently so hard, that steel of the highest temper makes no impression on them. Such are the precious stones or gems. Others yield with difficulty to the action of instruments; such are quartz, flints, agate, hard sandstone, porphyry, and granite. All these stones, when struck against a piece of steel, produce a great number of sparks; which circumstance has occasioned them to be called scintillant or sparkling. These sparks arise from small portions of the steel which are struck off by the stone, and suddenly set on fire by the strong percussion they undergo. This heat is so considerable, that the particles are melted; so that when collected on white paper, and observed with a good magnifier, they are found to be a kind of semi-vitrified calx, similar to that produced at iron forges. Stones that give fire having different degrees of consistence, from gems, and rock crystal, to the tender sandstones, and siliceous breccias of modern formation, the quantity of sparks must vary in the same proportion.

There is a great number of stones, whose aggregation is much less considerable, and which are soft enough to be cut and formed by steel instruments. These do not give fire with steel, but break with different degrees

grees of facility when struck with a hard tool. The difference of consistence in stones, which do not give fire with the steel, is observable in their other properties. Some, as for example marble and alabaster, receive a good and uniform polish; others, as for example, most of the calcareous stones, are capable of an inferior or false polish, and have always a dull greasy appearance. Some judgment may be formed of the kind of polish stones are capable of, by the appearance they exhibit when wetted; the moisture producing the effect of a polish while it lasts.

It is to be noted, that many stones may afford sparks, though they are not really of the class of scintillant stones. These are produced by their being of a mixed kind, and containing fragments of stones sufficiently hard to produce sparks. Thus it is that several kinds of calcareous marble give sparks, when struck with the steel, in consequence of the quartzose or flinty particles intermixed with their calcareous paste.

The density of stones is necessarily as their specific gravity. Some naturalists have considered this last property as very important for the classification of stony substances. M. de Buffon is of this opinion. But this character, however important for ascertaining the natural order and formation of these substances, requires accurate experiments to

be made, and cannot be used in the lithologic methods, in which facility and simplicity are necessary requisites to guide students at their entrance into this part of natural history.

§ III. Concerning the Fracture, considered as a Character of Stones.

When a stone is broken, the newly separated surfaces exhibit a peculiar arrangement of the integrant particles, which is different in different species. Lithologists call this appearance the fracture, and it affords very useful characters to distinguish stones from each other. By comparing the circumstances which relate to the fracture of all the stones we are acquainted with, it is easy to reduce these fractures to several kinds.

Some, for example, break like glass, with a polished surface, of a regularly curved figure, and this is called the vitreous fracture. It is observed in rock-crystal, quartz, &c.

Others present a surface clean and polished, but formed of successive undulations, resembling those observed on some shells. The two pieces applied together, in general fit each other very neatly. This fracture is distinguished by the name shelly, or shell like. The undulations are of various magnitudes and appearance, and may be observed

ed in several kinds of flint, jasper, agate, or petro-filex.

There is another class of stones, which, when broken, exhibit at their surfaces an assemblage of projecting points, resembling grains of sand worn by the waters. This is called the granulated fracture. It may be easily observed in sand-stone. The magnitude of these small parts affords a number of different distinctions. It is with relation to this kind of fracture, that we say a stone has a fine or a coarse grain.

Lastly, There is a great number of stones, whose fracture shews them to be composed of many equal laminæ placed upon each other. The great part of these being called spars, the fracture is thence denominated sparry, spathose, lamellated, or plated. These laminæ differ from each other in their extent, magnitude, thickness, transparency or opacity, horizontal or oblique position, with respect to the axis and diameter of the crystallized stone, that being supposed to be placed vertically. It is the various disposition of these in gems, calcareous or ponderous spars, crystals, &c. which sometimes causes the brilliant or chatoyant * appearance observed in talc, and the various kinds of feldt-

* We have no English word to express this modification of light.

spar,

spar, as the cat's eye, the avanturine, the labrador stone, &c.

Some authors have made divisions of stones, founded on their general appearance, together with their fracture. Cartheuser, in 1755, published a system of mineralogy, in which he distinguishes stones into lamellated, fibrous, solid, and granulated. But the fracture alone is insufficient to serve as the basis of a complete lithological method, but requires to be contrasted with the other characters examined in the present chapter. *

§ IV. Concerning Colour, considered as a Character of Stones.

The various colours observable in many stones, depend on combustible or metallic substances intimately combined with their other parts. In some specimens the colour is uniformly spread through the mass, in others it is seen only in certain specks or points. In general the colouring parts of stones is accidental, or not always found in the same kind, and varies according to circumstances. It is indeed true that the colour is sufficiently constant in some stones, as the gems, the schorls and tourmalins, to serve as one of the indications of their

* Vide L'Introduction à la Sciagraphie de Bergman par Mongez le jeune, page 21.

kind ;

kind; but as its utility in this respect is very confined, it is not much applied or esteemed by lithological writers.

Among the colours which serve to distinguish the sorts and varieties of stones, we may distinguish the uniform, or equally distributed colour, accompanied with transparency or opacity, and such as are unequally distributed in irregular spots, in veins, in points, and in bands. We must likewise pay attention to the quantity or number of colours which are sometimes observed, to the number of six or seven, as in marbles. From the number and disposition of the colours in these natural substances, it is that they have been divided into stones, of one, two, or three colours, variegated, spotted, veined, marbled, clouded, punctuated, or dotted, or bearing marks of vegetation, or other figures, &c.

§ 5. Concerning the Alteration produced by Fire, considered as a Character of Stones.

Some mineralogists, not content with examining stones by the exterior and sensible qualities, have also sought for means of distinguishing them by their chemical characters. The action of fire, and the alteration they are respectively subject to from this agent, has been regarded by many lithologists, as a good means for obtaining a knowledge

knowledge of their differences. They have observed that some, as for example, quartz, lose their transparency and hardness, by fire, but are no otherwise changed; that others suffer no change, as for example, rock crystal; that others again melt, and become converted into a glass of a different colour, as shorls, zeolite, asbestos, amianthus, granite; and lastly, that others lose their consistence, and part of their weight, without melting, and at the same time acquire the property of solubility in water, as all the calcareous stones do. Other experiments shew, that some stones lose their colour in the fire, while in others it is rendered deeper by the same agent. These are among the general results of the labours of Messrs. Pott, D'Arcet, and many other chemists.

These various alterations are necessary to be known, in order to render the history of stones more complete, and to shew their respective natures. They shew in general, that such stones as are the least changed by the fire, are the most simple; but they cannot be of any great utility in lithological methods, because they require the completion of experiments, which cannot be made but in a long time, and with considerable skill. Whereas the characters best calculated for the classification of stones, ought to be easy to be known or obtained, and either founded on such properties as the
eye

eye can ascertain, or at least may be collected from simple and ready trials or essays.

It is true indeed, when exterior properties are insufficient, that we may sometimes avail ourselves of the change produced in stones by fire, by the help of the blow-pipe recommended by Bergman; but however simple this ingenious method may be, it always implies the necessity of carrying an apparatus inconvenient to travellers, and the process is better calculated to be performed in a laboratory, than on a lithologic excursion.*

§ VI. Concerning the Action of Acids considered as a Character of Stones.

Acids are the solvents most commonly employed. Though we have not yet spoken of these salts, it is necessary we should, in this place, make a few remarks on the phe-

* See Bergman on the blow-pipe, at the end of his Chemical Essays, translated into English, and published in London, 1784.

If a blow-pipe, a piece of charcoal, a small silver spoon, and three small phials, containing salt of soda, microcosmic salt, and borax, compose an apparatus inconvenient to travellers, and if a process, easy to be executed in any place where a candle can be defended from the wind, require a chemical laboratory, the author is right in discouraging this excellent small analysis. Very complete apparatus for this purpose, are sold in London, contained in a box no larger than a book in twelves, at Brown's, bookseller, the corner of Essex-street, near the Strand. T.

nomena

nomena exhibited by some stones, when placed in contact with acids. The greater number are not at all acted on, or changed by acids; but there are some, which, upon a drop of nitrous acid being put on their surface, by means of a small tube, are acted on in such a manner, that the escape of bubbles, passing through the acid, occasions an appearance resembling ebullition. This phenomenon is called effervescence, and is owing to an aeriform substance separated from the substance by the action of the acid. The elastic fluid is itself a peculiar acid, disengaged by the acid dropped on the stone, and is the product of a true decomposition. All calcareous stones containing fixed air, effervesce by the contact of acids, and especially with that of nitre, which is usually employed in these essays. This disengagement of an aeriform fluid, shews in reality, that the matter it escapes from is a saline combination; but as it is a combination possessed neither of taste nor solubility in water, in any obvious degree, and as it besides forms a great part of the external crust of the globe, naturalists have always regarded it as a stony substance.

All stones may therefore be distinguished into effervescent and non-effervescent. A small phial of nitrous acid becomes, therefore, of course, a necessary article in such excursions as are made with the intention of collecting

collecting stones, and together with the maffier and the steel, is the only instrument necessary to be used by the lithologist.

Since Bergman has recommended the examination of stones by fire, with the assistance of the blow-pipe, they are essayed likewise with mineral alkali, borax and fusible salt of urine, which act differently on these matters according to their nature; and in general exhibit a fusion more or less complete, accompanied with different phenomena. We shall speak more largely on this method of analyzing stones, in the chapter wherein the other methods of analyzing them will be treated of.

C H A P. II.

The Lithologic Method of M. Daubenton, extracted from his *Tableau de Mineralogie*.

AMONG all the lithologists who have attempted the methodical distribution of stones, there is no one who has given divisions more exact, more clear, or more easy to be understood, than M. Daubenton. The skill with which this celebrated naturalist has contrasted the characters of these substances, renders his method much more accurate

curate and useful, than all those hitherto proposed. The properties he has selected as the bases of his characters, are all constant and easy to be known. They consist especially in the regularity or irregularity of form; transparency, more or less perfect, or opacity; consistence, or hardness, the polish stones are susceptible of; form, or respective arrangement of integrant parts, which occasions the vitreous, shell-like, granulated, lamellated, and spathose fractures; the colours, when they are not accidental; the surface, dull, brilliant, or chatoyant. As it would be impossible to improve on the precision and perspicuity of the system of M. Daubenton, we shall exhibit in this place his division of earths and stones, as he has laid them before the public in his *Tableau Methodique des Mineraux*.*

* *Tableau méthodique des Minéraux, suivant leurs différents natures, et avec des caractères distinctifs, apparens, ou faciles à reconnoître; par M. Daubenton, &c. Paris, chez Demonville, Pierres, Debure, Didot l'aîné, &c. 1784, in-8. de 36 pages.*

ORDER

ORDER THE FIRST.

MINERALS.

SANDS, EARTHS, AND STONES.*

These Substances do not dissolve in Water like Salts, nor burn like combustible Bodies, nor have the Brilliancy of Metallic Matters.

CLASS THE FIRST.

Stones that give Fire with Steel.

Genus I. Quartz.

Crystalline Substance, fracture vitreous not lamellated.

Species I. Opake, or semi-transparent Quartz.

Varieties.

- | | |
|---|-----------------|
| { | 1. fat |
| | 2. grained |
| | 3. milky |
| | 4. foliated |
| | 5. crystallized |

Species II.

* In this place, we only give a part of the table of M. Daubenton; but when we treat of the history of salts and combustible bodies, we shall give the divisions of this philosopher,

*Species II. Transparent Quartz, ROCK CRYSTAL.**Two Pyramids of six Faces, with or without a Prism
of six Sides (between them)*

Varieties.

- | | |
|---|--|
| { | 1. crystallized |
| { | 2. rough |
| { | 3. white |
| { | 4. red. <i>BOHEMIAN RUBY</i> |
| { | 5. yellow. <i>OCCIDENTAL
TOPAZ</i> |
| { | 6. ruddy or blackish.
<i>SMOAKY TOPAZ</i> |
| { | 7. green |
| { | 8. blue. <i>WATER SAPPHIRE</i> |
| { | 9. violet. <i>AMETHYST</i> |
| { | 10. iridescent |

Species III.

sopher, relating to these substances. As we have been careful to give an exact copy of his table, even so far as to use the same type or characters, we think it proper to subjoin the beginning of the advertisement of M. Daubenton, relating to the methodical division of stones." The following are the words of this celebrated naturalist.

" This table has been exposed in manuscript since the
 " year 1779, in the Hall of the College Royal during my
 " lectures; and many copies of it have been taken. I have
 " made various alterations, as I have received or acquired
 " new information respecting mineralogy. I have even a-
 " bandoned, for the present, my design of inserting the che-
 " mical analysis of different minerals in my tables, as I had
 " begun to do, because a sufficient number has not yet been
 " analysed. My principal object in drawing out this present
 " table,

pecies III. Quartz in agglutinated fragments,
Grit-stone, or Siliceous Grit,
granulated fracture.

- | | | |
|------------|---|--|
| Varieties. | { | 1. hard Grit-stone |
| | | 2. friable |
| | | 3. from the Levant. <i>Very fine grain</i> |
| | | 4. Filtering Stone. <i>Porous</i> |
| | | 5. Glittering |
| | | 6. veined |
| | | 7. exhibiting figures of plants |
| | | 8. coarse grained |

Species IV.

“ table, has been to facilitate the study of mineralogy. The
 “ best means of diffusing the knowledge of the sciences, is
 “ to simplify their elements. Methodical divisions promote
 “ this intention ; for though it is impossible to give descrip-
 “ tive characters perfectly agreeing with nature, yet such as
 “ they are, they are convenient, useful, and even necessary.
 “ In the full explanation of my table, which I propose to give
 “ in my *Leçons d'Histoire Naturelle*, now in the press, I
 “ shall shew the advantages and defects of my methodical dis-
 “ tribution of minerals. I shall only take notice in this
 “ place, that minerals are distributed in this table into orders,
 “ classes, species, and varieties. The distinctive characters
 “ of each article of these methodical divisions are printed in
 “ *Italic.*”

“ Among the names, there are some in Roman capitals,
 “ and others in Italic capitals. The former are such as I
 “ think most suitable to the things they denote ; the others

Species IV. Quartz, in loose Grains, SAND,

vitreous Surface.

- Varieties. {
1. angular
 2. rounded
 3. moving
 4. fluid

Species V. Quartz in concrete Masses.

Sandy and quartzose Pudding Stones, or breccias.

Genus II. Semi-transparent Stones,

vitreous fracture, sometimes conchoidal.

Species I. Agates.

*of all colours, except the milk white, the
fine red, the orange, and the green.*

- Varieties. {
1. clouded
 2. punctuated
 3. spotted
 4. veined
 5. onyx
 6. irised
 7. presenting the appearance
of herbs
 8. presenting the appearance
of moss

“ are synonymes, whose use would be attended with incon-
“ venience, and are inserted only to facilitate the know-
“ ledge of the things described.”

Species II.

*Species II. Chalcedonies,**milky transparency*

- Varieties. {
1. reddish
 2. blueish
 3. veined
 4. onyx
 5. iridescent. OPALS
 6. rounded and solid. GIRASOLS
 7. rounded and hollow. HYDROPAL CHALCEDONY (Enhydre)
 8. in stalactites
 9. in sediment
 10. hydrophanes

*Species III. Carnelians,**beautiful red*

- Varieties. {
1. pale
 2. punctuated
 3. onyx
 4. exhibiting figures of herbs
 5. in stalactites

*Species IV. Sardonyx,**orange colour*

- Varieties. {
1. pale
 2. veined
 3. onyx
 4. presenting figures of herbs
 5. blackish

Species V. Flints,

grey, white, reddish, blackish.

Varieties. { 1. with tubercles
2. in layers

Species VI. The Prasem,

green.

Varieties. { 1. green
2. clouded
3. spotted

Species VII. Jade,

greasy polish.

Varieties. { 1. whitish
2. olive colour
3. green

Species VIII. Petrofilex,

transparency of wax, conchoidal fracture.

Varieties. { 1. white
2. reddish
3. veined

Genus III. Opaque Stones,

vitreous fracture, sometimes conchoidal, or dull

Species I. Mill Stone,

more or less porous.

Varieties. { 1. porous
2. dense or full

Species II.

*Species II. Pebbles,**concentric layers.*

Varieties.

1. spotted
2. veined
3. onyx
4. oculiform
5. presenting the figure of herbs
6. concreted into breccias.

PUDDING STONES

*Species III. Jasper,**vitreous fracture, often dull, and without concentric layers.*

Varieties.

1. green
2. red
3. yellow
4. brown
5. violet
6. black
7. grey
8. white
9. clouded
10. spotted
11. veined
12. onyx
13. flowered
14. universal
15. fragments united in breccias

Genus IV. Scintillating Spar. FELD-SPATH.

Species I. Feld-Spath, regularly crystallized.

- | | | |
|------------|---|---|
| Varieties. | { | 1. in oblique (angled) prisms
of four sides
2. in six-sided prisms, with
summits of two planes
3. in ten-sided prisms, with
summits of two planes and
four facets |
|------------|---|---|

Species II. Feld Spath crystallized confusedly

- | | | |
|------------|---|---|
| Varieties. | { | 1. white
2. pearl grey. FISHES EYE
3. red
4. red with brilliant spangles.
NATURAL AVANTURINE
5. green
6. blue
7. violet
8. green and blue, by inter-
nal reflection. LABRA-
DOR STONE
9. variously coloured, by in-
ternal reflection. CAT'S
EYE |
|------------|---|---|

Genus V. Crystal Gems,

*transparent and lamellated, not electrifiable by heat
alone without friction.*

Species I. Red,

- | | | |
|------------|---|---|
| Varieties. | { | 1. Garnets
crystallized with 12, 36, or
24 facets. There are also
yellow, brown, &c. garnets
2. The |
|------------|---|---|

- Varieties. { 2. The balass Ruby
rose colour, octahedral crystals

Species II. Red and orange

- Varieties. { 3. Spinell Ruby
fire colour, crystallized like the balass Ruby
4. Vermillion
crystallized like the garnet
5. Hyacinthe-la-belle
crystallized under 4 hexagonal sides with summits having 4 Rhomboidal facets.

Species III. Orange coloured.

- Variety 6. Hyacinths
crystallized like the Hyacinthe-la-belle

Species IV. Yellow.

- Varieties. { 7. oriental Topaz
crystallized in 2 Pyramids of 6 facets
8. Saxon Topaz
crystallized in prisms of eight sides, with summits of 13 faces

Species V. Yellow and green.

- Variety. 9. Peridots, CHRYSOLITES,
crystallized in a prism of 6 sides, with Pyramids of 6 faces

Species VI.

Species VI. Green.

Variety.

10. Emeralds of Peru
*crystallized in six-sided
Prisms.*

Species VII. Green and blue.

Variety.

11. Aqua-marine
*crystallized like the Saxon to-
paz*

Species VIII. Blue.

Variety.

12. Oriental Sapphire
*crystallized like the oriental
topaz*

Species IX. Indigo.

Variety.

13. Indigo Saphir
*crystallized like the oriental
topaz and sapphire*

Species X. Red and violet.*

Varieties.

- { 14. Syrian Garnets
crystallized like the garnet
15. oriental Ruby
*crystallized like the Topaz
and oriental Sapphire*

* Such Gems as are formed without colouring matter are white. Note of M. Daubenton.

Genus VI. Crystal Gems, Tourmalins,
*composed of laminae perpendicular to the axis of the
 crystal, electric by heat alone without friction.*

Varieties.

1. Brazilian Ruby
*red in a prism of four sides,
 with pyramids of four facets*
2. Brazilian Topaz
*yellow, crystallized like the
 Brazilian Ruby*

Genus VII. Tourmalins,
*electric by heat alone without friction, and without
 laminae perpendicular to the axis of the crystal.*

Varieties.

1. Tourmalins of Ceylon
*transparent, orange coloured,
 not much furrowed on the
 surface*
2. Tourmalins of Spain
*transparent in a strong light,
 orange coloured, very much
 furrowed*
3. Tourmalins of Tyrol
*transversal fissures in the
 prism*
4. Tourmalins of Madagascar
 SHORTS OF MADAGASCAR,
 opaque, black
5. Lenticular Tourmalins
6. Peridots of Ceylon
*yellow and green, much fur-
 rowed*
7. Peridots of Brazil
*yellow and green, much fur-
 rowed*

8. Emeralds

- Varieties. { 8. Emeralds of Brazil
green
9. Sapphire of Brazil
blue †

Genus VIII. Shorls,

Not electric by heat without friction, opaque crystals, or long green semi-transparent needles.

Species I. Crystallized Shorls.

- Varieties. { 1. oblique (angled) prism of four
fides
2. six-sided prism
PIERRE DE CROIX
3. six-sided prism, with summits of
2 facets, or pyramids of three or
four facets
4. eight-sided prism with summits
of two faces

Species II. In articulated fragments.

- Varieties. { 1. Spathose Shorl.
striae with Spathose facets
2. in Masses. SHORL PASTE
(Paste de Shorl) brilliant points
in the fracture

Genus IX. Azure Stone,

opaque and blue

- Varieties. { 1. purplish blue
2. blue

† All these Tourmalins, except the lenticular, are crystallized in nine-sided prisms, with summits of three or six facets. Note of M. Daubenton.

CLASS

CLASS THE SECOND.

*Earths and Stones, which do not give Fire
with Steel, and do not effervesce with Acids.*

Genus I. Clays,

*when moist they are ductile; when dry they take a
polish, by being slightly rubbed with the hand.*

Species I. Clays absolutely infusible,

- Varieties. {
1. used to make pots for the glass-
house
2. for tobacco pipes

Species II. Clays partly fusible,

- Varieties. {
1. for porcelain
2. for English pottery
3. for stone-ware

Species III. Clays intirely fusible,

- Varieties. {
1. for common pottery and delf-
ware
2. for Fayence
3. for chimney tiles (Dutch tiles)
4. for tiles
5. for bricks

Genus II.

Genus II. Shiftus,

argillaceous and foliated fracture.

Varieties.

- | | |
|---|---------------------------------|
| { | 1. black stone |
| | 2. common Shiftus or slate |
| | 3. writing slate |
| | 4. polishing stone : |
| | 5. green stone |
| | 6. Hone (Pierre à raser) |
| | 7. fragments united in breccias |

Genus III. Talc,

*polished glittering plates, without Spathose fracture.**Species I.* Talc in large leaves or plates.

Variety. Muscovy talc.

Species II. In small leaves.

Variety. Mica

Genus IV. Steatites,

*greasy feel, like tallow**Species I.* Steatites in laminæ.

- | | |
|---|--------------------------------------|
| { | 1. fine French chalk (de Briançon) |
| | 2. coarse French chalk (de Briançon) |

Species II. Compact Steatites.

- | | |
|---|-------------------------------|
| { | 1. Soap Rock (Pierre de lard) |
| | 2. Spanish chalk |

Species III. Lapis ollaris.

- | | |
|---|---------------------------|
| { | 1. Como Stone |
| | 2. foliated Lapis ollaris |

Genus V.

Genus V. Serpentine,

the polish and colours of marble.

Species I. Opake serpentines.

- Varieties. { 1. spotted
2. veined

Species II. Semi-transparent Serpentine.

- Varieties. { 1. granulated
2. fibrous
-

Genus VI. Amianthus,

filaments not calcinable, flakes or leaves lighter than water.

Species I. Amianthus with soft (or flexible) fibres.

- Varieties. { 1. Amianthus with long fibres
2. with short fibres

Species II. Amianthus, with hard (or brittle) fibres.

- Varieties. { 1. Asbestos, easily separable into parts (mur)
2. Asbestos, difficultly separable (non mur)

Species III. Amianthus in flakes or leaves.

- Varieties. { 1. fossil leather
2. fossil cork
-

Genus VII. Zeolite,

crystallized in divergent radii, or convertible into a gelly by solution in acids.

Species I. Crystallized Zeolite.

Species II. Compact Zeolite.

- Varieties. { 1. white
2. blue
3. red

Genus VIII.

Genus VIII. Fluor Spar,

fragments with triangular faces, all inclined to each other.

Species I. Fluor Spar in crystals.

- Varieties. {
1. octahedrons
 2. cuneiform octahedrons
 3. with 14 faces
 4. cubic

Species II. Fluor Spar in irregular Masses.

Genus IX. Ponderous Spar,

rhomboidal fragments, the lateral faces perpendicular to the bases

Species I. Crystallized Ponderous Spar.

- Varieties. {
1. in rhomboidal plates
 2. in octahedrons with acute summits
 3. in octahedrons with obtuse summits
 4. in hexagonal plates with acute summits
 5. in hexagonal plates with obtuse summits
 6. in tables
 7. in cock's combs (or lenticular)

Species II. Ponderous Spar crystallized confusedly

BOLOGNA STONE.

Genus X. Heavy Stone. **TUNGSTEN,**

resembling Fluor Spar in the form of its fragments, but much heavier; it becomes yellow in acids.

CLASS

CLASS THE THIRD.

*Earths and Stones which effervesce with Acids.**

Genus I. Calcareous Earths.

Effervescence with Acids.

Species I. Compact.

Variety. Chalk.

Species II. Spongy.

Variety. Stone-marrow.

Species III. In powder.

Variety. Fossil Flour.

Species IV. Consistence of cream.

Variety. Lac lunæ.

Species V. Figured.

Variety. Congealed.

* Though these substances are at present regarded by chemists as neutral salts, formed by the union of lime and cretaceous acid, we think it proper to exhibit them in this place, at the end of earthy substances, in order to give a connected view of the method of M. Daubenton. Naturalists, who avail themselves of external and striking characters in their distribution of substances, act properly in ranking them among earths. They will be considered under another point of view in the history of saline matters. Note of Mr. Fourcroy.

Genus II. Calcareous stones.

Colours and polish are bad.

Species I. Coarse grained.

EXAMPLE.

Limestone from Arcueil.

Species II. Fine grained.

EXAMPLE.

The Thunderstone.

Genus III. Marbles.

Granulated fracture, fine colours, good polish.

Species I. Marbles of six colours.

Varieties. { White, grey, green, yellow, red,
and black.
EXAMPLE.
Marble from Wirtemberg.

Species II. Marbles of two colours.

Varieties. { 15 in number, formed by the com-
binations of 6 colours, 2 together.
EXAMPLE.
white and grey.
Marble of Carrara.

Species III. Marbles of three colours.

Varieties. { 20 in number, formed by the combi-
nation of 6 colours, 3 together.
EXAMPLE.
grey, yellow, and black.
Lumachello.

Species

Species IV. Marbles of four colours:

- Varieties. { 15 in number, formed by the combination of 6 colours, 4 together.
- EXAMPLE.
- white, grey, yellow, and red.
Brocatello from Spain.

Species V. Marbles of five colours.

- Varieties. { 6 in number, formed by the combinations of 6 colours, 5 together.
- EXAMPLE.
- white, grey, yellow, red and black.
Breccias of old Castile.

Genus IV. Calcareous Spar.

*Regular form, spathose fracture.**Species I. Crystallized calcareous spar.*

- Varieties. { 1 obtuse rhomboidal figure.
Island Spar.
- 2 lenticular rhomboidal figure.
- 3 lenticular rhomboidal figure, with 6 triangular faces.
- 4 acute rhomboidal figure.
- 5 with 12 pentagonal faces.
- 6 with 3 triangular faces.
- 7 six-sided prism.
- 8 six rhombic sides, with 6 faces lozenge-wise.
- 9 with 12 scalene triangular faces.
- 10 with 12 faces of 4 or 5 sides, and 6 quadrilateral facets.
- 11 with 6 hexagonal faces, and 12 quadrilateral facets.

Species II. Striated calcareous spar.

Varieties. { 1 in parallel striæ.
2 in divergent striæ.

Genus V. Concretions.

Successive coats.

Species I. Stalactitical Concretions.

Varieties. { 1 in columns
2 tabular
3 resembling alabaster.

Species II. Concretions by incrustation.

Species III. Concretions by sediment.

Varieties. { 1 by horizontal sediments.
2 by rounded sediments.

CLASS THE FOURTH.

Mixed Earths and Stones.

Mixed earths.

Genus I. Sand and clay.

Species. Sand for founders.

Variety. Sand from Fontenai-aux-roses.

Genus

Genus II. Sand and calcareous earth.

Genus III. Clay and calcareous earth.

Species. Marle.

- | | | |
|------------|---|---|
| Varieties. | { | 1 marle, armenian bole. |
| | | 2 marle, sealed earth. |
| | | 3 stone for taking spots out of cloth.
(pierre à detacher) |
| | | 4 fuller's earth. |
| | | 5 porcelain earth. |
| | | 6 pipe clay. |
| | | 7 potter's clay (terre à fayance) |
| | | 8 white marle. |
| | | 9 marle in flakes. |
| | | 10 marle for manure. |

Mixed stones,

OF TWO GENERA.

- | | | |
|-------------------------------|-----------|--|
| Quartz and scintillating spar | - - | Granitin. |
| Quartz and schorl | - - - - - | Granitello. |
| Quartz and steatites | - - - - - | Quartzose steatites. |
| Quartz and mica | - - - - - | Micaceous quartz. |
| Transparent quartz and mica | - | Micaceous crystal. |
| Quartz in grit and gem stone | - - | { 1 Garnet on grit
stone.
2 Garnet in grit
stone. |

Quartz in grit and mica - - -	Micaceous grit.
Quartz in grit and calcareous matter	{ 1 crytallized grit. 2 grit in stalactites.
Quartz in sand and opake stone	{ sandy and filiceous breccias.
Quartz in sand and schistus	{ scintillating schistus <i>hornstone. trap.</i>
Quartz in sand and zeolite - -	scintillating zeolite.
Scintillating spar and paste, or cement, of schorl	{ ophites.
Semi-transparent stone, with opake stone	{ jasperated agate, or agatized jasper.
Schorl and mica - - - - -	{ micaceous spathose schorl.
Schistus and mica - - - -	micaceous schistus.
Schistus and marble - - -	Florence marble.
Serpentine and marble	{ 1 green Egyptian marble. 2 sea green marble. 3 green antique marble. 4 green marble of Suza. 5 green marble of Varalta.
Ponderous spar and calcareous matter	{ alkaline ponderous spar.

OF THREE GENERA.

Quartz in sand, shistus and } Rough wheat-stone.
mica

Quartz, gem, and mica - - garnet rock.

Quartzose paste, scintillating }
spar in large fragments and } porphyry.
schorl

Quartzose paste, scintillating }
spar in large fragments and } serpentine. *hard ser-*
schorl *pentine.*

Quartz schorl and steatites - tuberculous rock.

Quartz, scintillating spar and } granite.
schorl

OF FOUR GENERA.

Quartz, scintillating spar } granite.
schorl and mica

OF SEVERAL GENERA MORE OR }
LESS IN NUMBER, UNITED IN } universal breccias.
BRECCIAS.

DOUBLE BRECCIAS.

Varieties. { 1 Fragments of porphyry, with a paste of
porphyry.
2 Fragments of granite, with a paste of
schorl.

VOLCANIC PRODUCTS.*

Genus I. Lavas, or volcanic Matters; that is to say, formed by Volcanos.

Species I. Porous Scorizæ.

Varieties.

- | | |
|---|--------------------------|
| { | 1. in irregular masses |
| | 2. in striped masses |
| | 3. in stalactical forms |
| | 4. in fragments. LAPILLO |
| | 5. in small Fragments. |
| | POUZZOLANA. |
| { | 6. in Powder. VOLCANIC |
| | CINDERS. |

Species II. Basaltes.

compact and scintillating, blackish cinereous fracture, with brilliant points, without small plates, like those of scintillating Shistus.

Varieties.

- | | |
|---|-----------------------------|
| { | 1. in irregular masses |
| | 2. in round masses |
| | 3. in flat masses or tables |
| | 4. in prisms of 3, 4, 5, 6, |
| | 7, 8, or 9 sides |
| { | 5. in articulated prisms |

Species

* M. Daubenton places the volcanic products at the end of the minerals, without ranging them under any one of the four orders that constitute his method. As it is usual to study the history of those substances together with stones, I have thought proper to adjoin them here. F.

Species III: Glafs.

Varieties.	{	1. in detached fibres
		GLASS GALL
		2. in agglutinated fibres
		PUMICE STONE
		3. in compact masses
		VOLCANIC SCORIA.
		LAPIS OBSIDIANUS.

Genus II. Volcanified Matters or Substances altered by the heat of volcanos appearing to have been *baked, calcined, melted, or vitrified.*

Species I. Granite.

II. Garnet.

III. Hyacinth.

IV. Mica.

V. Peridot.

VI. Quartz.

VII. Schorl.

VIII. Scintillating Spar.

IX. Calcareous Matters.

X. Baked Earths, Tripoli.

STONES,

STONES, whose nature is not sufficiently known to indicate the classes to which they belong.

Jargon of Ceylon,

crystallized in rectangular prisms, with pyramids of 4 triangular faces.

It seems that the name of Jargon is given to many stones, whose structure is yet unknown.

Macles,

in square prisms or cylinders, whose transverse section presents a blue cross.

The Macle has been regarded as a schorl; but this opinion is not yet proved.

White Chrystals,

in flattened prisms of 10 sides, with 2 summits of 4 faces, one forming a concave, and the other a convex solid angle.

Violet or green Chrystals,

rhomboidal with 2 facets instead of two opposite angles.

The name of Schorl has been given to these white, violet, and green crystals, though they do not appear to be of the nature of Schorls.

C H A P.

C H A P. III.

On Classification of Earths and Stones, according to their Chemical Properties.

CHEMISTS, who have employed themselves in the examination of minerals, have adopted the opinion, that it is of importance to ascertain their mutual agreement or difference from their respective nature and chemical properties. And though their labours have not yet been sufficiently diversified and extended with respect to earths and stones, to afford a foundation for any very accurate arrangement of these substances on such principles; it is, nevertheless, of importance to know the actual state of the information we possess, concerning their chemical properties, and the influence those properties may have on the method of classing them.

Among the many philosophers who, since the time of Cronstedt, have availed themselves of the chemical properties in the classification of earths and stones, Mess. Bucquet, Bergman, and Kirwan, have succeeded the best, and have exhibited the most valuable and complete systems of lithology, considered

sidered chemically. The order followed by these three chemists, not being the same, and each possessing its own peculiar advantages, we think proper to explain them in order, at the same time pointing out their respective defects.

§ 1. The Chemical Division of Earths and Stones, proposed by M. Bucquet.

Mr. Bucquet, after having long endeavoured to unite the distinctive external characters made use of by naturalists in their arrangement of earths and stones, with those which chemistry affords, had at length adopted a compound arrangement, which he proposed to have used in his lectures, when his death deprived the scientific world of continuance of his labours. In the conversations I had the happiness to enjoy with him during the lingering illness to which he at last fell a sacrifice, I collected every detail relative to his lithologic method; and the fruits of these valuable conversations have been already communicated to the public in the first edition of this work. I shall here repeat the same, with the addition of such notes as the labours of men of science since that period have rendered necessary.

According to Mr. Bucquet, earths and stones are divided into three sections.
The

The first comprehends the simple earths and stones ; the second, the compounds of those simple bodies ; and the third, the mixtures of either or both.

Simple earths and stones in a state of purity are insipid, dry, hard, insoluble and infusible substances. If some of these appear to possess these characters in an inferior degree, more particularly by being in certain manner fusible, it is always to be attributed to the admixture of foreign matters. The chemical analysis shews their purity, by its insufficiency to separate them into other more simple substances.

Compound earths and stones must be considered as combinations of different simple earths, with saline and metallic substances. These combinations have been made in the great laboratory of nature, by means of water, or of fire. Their chemical characters are fusibility with various kinds of glass, and the property of being separated into other more simple substances by the action of solvents, more especially acids.

Mixed earths and stones are known to be such by the eye. They are seen to be composed of an irregular assemblage of different stones or earths, either simple or compound. It may readily be conceived that this irregular mixture must be mechanically separated into its parts before the chemical analysis can

can be proceeded on, which must be done by the examination of each kind by itself.

S E C T I O N I.

Simple Earths and Stones are divided into four Orders.

ORDER I. VITREOUS STONES:

They possess extreme hardness and perfect transparency; their fracture is vitreous; they give fire with the steel; and the action of heat alters neither their transparency nor their hardness.

This first order contains two genera; rock crystal, and the vitreous precious stones.

Genus I. ROCK CRYSTAL.

Rock crystal exhibits all the characters of vitreous precious stones, in the most eminent degree. It is distinguished from the following genus by its fracture, which is similar to that of glass.

Its various kinds may be distinguished

1. *With respect to their form.*

Species.

1. Solitary hexahedral crystals, with two hexahedral pyramids. According to the Abbé Rochon, they produce the division of light usually called double refraction.

2. Hexa-

2. Hexahedral crystals in groups, with one or two points.
3. Tetrahedral, dodecahedral, flattened, &c. crystals. These are always hexahedral crystals, whose facets are varied and singular.
4. Rock crystal, in masses; from Madagascar. It has not the property of double refraction.

2. *With respect to colour.*

5. Reddish rock crystal.
6. Smoaky crystals.
7. Black crystals.
8. Yellow crystals.
9. Blue crystals.
10. Green crystals.

3. *With respect to accidental events.*

11. Hollow rock crystal.
12. Containing water.
13. One crystal included within another (emboîtés).
14. Rounded; pebbles from the Rhine.
15. Encrusted with metallic calces
16. In gæodes.
17. Containing amianthus.
18. Containing Schorl.
19. Encrusted with pyrites.

Their formation by water is proved

1. By their transparency.
2. By the form of small crystals.
3. By the inclosure of one crystal in another.

4. By

4. By their including substances alterable by fire.

These substances are cut and polished into the form of vases and into toys.

Genus II. VITREOUS PRECIOUS STONES.

The precious stones placed under this division have all the characters of rock crystal, and more particularly its unchangeableness by fire. Though this arrangement may seem an inversion of the natural order, and Bergman has assured us, that he has found these stones to consist of several matters combined together; yet in their hardness, transparency, and habitudes in the fire, they greatly resemble rock crystal. They differ from it, however, in their superior hardness, more lively and clear colour, and in their fracture, which is lamellated. The chemical difference which exists between all precious stones, more especially as far as relates to the alterations produced in them by fire, induced M. Bucquet to separate them from each other, and to include them respectively in such orders of stones as they appeared to resemble the most.

The following four precious stones are distinguished from the rest, by the appellation vitreous.

Species

Species.

1. Oriental topaz.
2. Hyacinth.
3. Oriental sapphire.
4. Amethyst.

M. Daubenton always regarded this last as a quartz crystal.

Order II. Quartzose Stones.

They have less hardness and transparency than the foregoing. Their fracture is vitreous, and they strike fire with steel. Heat causes them to lose their hardness and transparency, and reduces them to a white and opaque* earth. We shall range four genera of stones under this order.

Genus I. QUARTZ.

Has all the preceding characters.

Species.

1. Transparent quartz, crystallized in hexagonal pyramids, without prisms of any sensible length, or with very short prisms.
2. Transparent quartz in masses.

* It is on account of their different habitudes in the fire, that M. Bucquet thought it proper to distinguish quartz from rock crystal, and to make a particular genus of each. He has also observed, that this stone quenched in water, after having been heated red for several successive times, communicated acid properties to the fluid. Future experiments must determine whether this distinction be well founded. F.

3. Opake, or milky quartz.
4. Fat quartz.
5. Weathered or rotten quartz.
6. Green, blue, or violet quartz;
prism of amethyst.
7. Yellow quartz of a lamellated fracture.

Topaz { Saxon.
 { Brazilian.

These topazes have all the characters of quartz.

Genus II. FLINT, AGATE.

Flints and agates form small round masses, most commonly opake) though sometimes semi-transparent) either hollow or solid, variously coloured and disposed in strata; in chalk, as is the case with flints; or in clay, as are the agates. Their fracture is sometimes scaly.

Species.

1. Grey flint.
2. Yellow flint.
3. Red flint.
4. Corneous flint; gun-flint.
5. Brown flint; Egyptian.
6. Transparent spotted flint; German agate.
7. Red agate; Cornelian.
8. Pale red agate.
9. Brown or yellow agate; sardonyx.
10. Onyx; concentric laminæ.

11. La-

11. Laminated agate, disposed in horizontal layers. Much of the appearance of the laminæ, and their position relative to the figure of the stone, depends on the cutting.
12. Agate with figures. { Dendrites; herborized agates.*
Antropomorphites.
Zoomorphites.
Uranomorphites.
13. Agate apparently mouldy, or marked with small greenish points, generally owing to mosses.
14. Agate of four colours; elementary.
15. Grey agate; grey chalcedony.
16. White or milky agate { in beds.
chalcedony. { in stalactites.
worn round; cacholong.
17. White agate, reflecting the light in a peculiar manner called chatoyant { Chatoyant agate of the lapidaries.
Cat's eye.
Oculus mundi, or hydropthane.
Opal.
Girasol.
18. Brown agate, with brilliant gold coloured specks. Aventurine.
19. Oriental agate.
20. Agate inclosing water.

* M. Daubenton has shewn, in a memoir read to the Academy, that herborized stones contain very fine mosses, or small grains of black iron ore.

That the formation of quartz, agates, and flints, is owing to water, is evident from

1. Their form.
2. Their laminæ, or beds.
3. Their mosses.
4. The water they contain.
5. The organic matters included in them, as in the mossy or mouldy agates.

The history of the gæodes likewise prove this truth. These are stony boxes filled with crystals; in which flint and quartz are found disposed in concentric laminæ.

Genus III. Organic Matters converted into Silex, or Agate.

The organic form still visible, together with the characters of quartzose stones, distinguish them from the three other genera of this order.*

Species.

1. Petrified wood; still fibrous, and susceptible of polish.
2. Wood, whose species is distinguishable on account of its texture. Fir.
3. Sea urchins and madrepores, converted into flint.

* It would, perhaps, be much more natural to form a particular class of animal and vegetable substances, altered during their stay in the earth. This class might be named fossils, and might be placed at the end of the organized kingdom. Note of the author.

4. Shells

4. Shells agatified.
5. Carpolites ; these have been falsely regarded as petrified fruits ; they are small ludus helmontii filicified.
6. Entrochites.
7. Lapis frumentarius filiceus.

It gives fire with the steel, does not effervesce with acids, and seems to be formed by the assemblage of cornua ammonis, divided perpendicularly to their volutes.

There are two opinions concerning petrification. According to the one, the organized matters are entirely converted into stone. According to the other, the void spaces left in soft earths by animal substances, or the intervals in the texture of vegetable bodies, have been filled by the gradual deposition of earthy matter. It has been observed, that vegetable matters almost always become quartzose, while animal matters most commonly become calcareous, and that vegetables scarcely ever pass into the calcareous state, at the same time preserving their texture.* This observation

* Since the discovery of the sparry gas, which has the property of depositing quartzose earth, some naturalists have thought that petrification is owing to a similar phenomenon ; but this opinion can be only regarded as an hypothesis, till the existence of an acid holding quartzose earth in solution in the bowels of the earth can be shewn. Note of the author.

may suffice to shew, that there is no such thing as petrification properly so called, or real change of organized substances into stone. For, 1. Shells and madrepores suffer no other change than the loss of their mucilage or animal gluten by putrefaction, and become thin calcareous skeletons, such as they existed entire during the life of their inhabitants. 2. The pretended petrifications of wood, are nothing more than depositions of vitrifiable earth. In proportion as the fibres are destroyed by putrefaction, quartzose earth is deposited in the cavity, which retains the organic figure, and at length when no more vegetable matter is left, the petrification is completed.

Genus IV. JASPER.

Jasper possesses all the characters of quartzose stones. It is not fusible; but loses its aggregation by heat. It is a very hard stone, susceptible of a beautiful polish, opaque, and variegated with different colours. Its fracture is vitreous and dull. It is very seldom ranged in strata; but most commonly forms considerable masses or veins in rocks. It is also found in small round masses. Most of the samples of jasper are mixtures of quartz and chalcedony. Some contain calcareous spar.

The species of jasper have been greatly multiplied

multiplied by naturalists. They may be reduced to the following :

Species.

1. White jasper.
2. Grey.
3. Yellow.
4. Red.
5. Brown.
6. Green.
7. Veined.
8. Spotted.
9. Green, with red points. Blood stone.
10. Flowered.

Toys, and more especially cups and saucers, are made of jasper. Many antique sculptures are in stones of this nature.

Genus V. Grit-stone, or Free-stone.

Grit-stone is opaque, of a granulated fracture, much less hard than quartz or flint. It exists in enormous masses, more or less hard, and of a grain coarser or finer in different specimens.

Species.

1. Grit-stone crystallized in rhomboids. M. de Laffone has proved that their figure is a consequence of their containing calcareous earth.*

* Memoirs of the Academy of Sciences for the year 1777.

2. Grit-stone in the form of cauliflower, balls, &c.
3. Grit-stone in stalagmites.
4. White.
5. Grey.
6. Red.
7. Black, or brown.
8. Veined.
9. Figured, or dendritical.
10. ———, whose aggregation is destroyed; sand.

The following are the varieties of sand:

Varieties.

1. Quick-sand.
2. Angular sand.
3. Sand rounded by the action of water.
4. Pure white sand.
5. Micaceous sand; glare.
6. Yellowish sand mixed with clay; founder's sand.
7. Ferruginous sand; yellow.
8. Ferruginous sand; black.
9. Blue sand; from copper.
10. Violet sand; from tin.
11. Auriferous sand.

Order III. Argillaceous Earths and Stones.

They have a greasy feel; are kneadable; stick to the tongue when dry; are foliated; often coloured; are disposed in beds or strata, and in large masses.

Their

Their aggregation is less strong than that of quartzose stones. They have a greater tendency to combination, and are therefore mostly altered. Heat causes them to contract in their dimensions, and gives them so great a degree of hardness, that they emulate the quartzose stones, and like them give fire with the steel. Water reduces them into paste, and in larger quantities divides them, and renders them pure by the mechanical subsidence of the grosser substances they may contain. They retain water so strongly, that they cannot be again totally deprived of it.

Part of their substance combines with acids. Some chemists have supposed that clay is nothing but the siliceous earth changed by the vitriolic acid; but this opinion is not founded on any direct proofs.

Many naturalists have thought that vitrifiable earths, by long exposure to external agents, water, air, and heat, become more and more divided, and are at last reduced to such a degree of subtlety, as to be soft to the touch, and susceptible of union with water; or in a word, that they become clay. This theory being founded on some accurate observations, seems to deserve more confidence than the former; but neither the one nor the other are completely proved.

On the two properties of clay, namely, its ductility when softened by water, and the hardness

hardness it acquires by baking, are founded the arts of making tiles, bricks, and all the varieties of pottery; the details of which belong to the history of these earths.

Naturalists have described a great number of species of argillaceous earths; and have confounded with them many which are not argillaceous, as well as certain compound stones, as serpentine, zeolite, trapp, &c.

The name of argill, or clay, ought not to be given to any earths but such as harden in the fire, are kneadable with water, and form alum with the vitriolic acid.

M. Macquer, who has examined a great number of clays,* found none absolutely pure. The colour and fusibility of many of the specimens, are owing to the admixture of different combustible and metallic substances.

The late M. Bucquet distinguished them into four genera.

Genus I. SOFT AND DUCTILE CLAYS.

They may be kneaded when first dug out of the earth; they become dry in the air.

Species.

1. White clay; pipe clay.
2. Sandy clay.

* Academie des Sciences, 1758.

3. Ductile

3. Ductile blackish clay ; for white pottery.
4. Clay with mica, kaolin ; partly fusible ; for porcelain.
5. Metallic clay ; fusible ; sealed earth, Armenian bole.
6. Pyritous clay ; fusible ; blue, green, or marbled ; for common pottery.

Genus II. DRY FRIABLE CLAYS, TRIPOLIS.

All the clays which M. Bucquet ranked among the tripolis, are found dry in the earth. They are all formed in beds or strata, frequently very thin. They all wear away by rubbing with the finger, and are reduced into powder. They imbibe water with great avidity, and stick to the tongue.

1. Dry, grey, foliated clay ; fuller's earth.
2. Red tripoli. Some suppose it to be a volcanic production.
3. Grey tripoli.
4. Black tripoli.
5. Rotten stone ; of an olive grey.

Genus III. Shifti.

The shifti are laminated stones, which easily split into plates ; they are very much compounded and fusible. They form large blocks, placed with various degrees of obliquity

liquity in the interior parts of the globe. Almost all the quarries of this substance have impressions on their upper surfaces, of parts of plants, of the classes of rushes, fern, &c. and of shells, fishes, insects, &c.

Species.

1. Black shiftus, friable ; ampelite.
2. Fissile shiftus, slate.
3. Black shiftus, hard, slate for writing.
4. Red, brown, &c. shiftus.
5. Shiftus, with vegetable and animal impressions.
6. Very hard shiftus, for sharpening razors.

Genus IV. FELDT-SPAR.

It is formed by rhomboidal laminæ ; its fracture is spathose ; it gives fire with the steel ; whence it has been called spatium scintillaris. It is harder than the shiftus, and is fusible. Mr. Bucquet thought it to be an argillaceous stone, coloured by iron. M. Monnet says it is composed of quartz, clay, magnesia, and a small portion of calcareous earth. The difference of opinions respecting the nature of feldt-spar, arises from its not being yet well known. Future experiments may serve to fix its place.*

Species.

* Father Pini, an Italian naturalist, is the first who discovered the feldt-spar in a crystallized form. Since his time it

Species.

1. Prismatic feldt-spar.*
2. White feldt-spar.
3. Red feldt-spar.
4. Green feldt-spar.
5. Blue feldt-spar.

Order IV. False Clays.

They resemble clays only in their foliated texture, and greasy appearance; some harden in the fire.

They differ from clays, in not making a paste with water; and most part of them melt in the fire. With the vitriolic acid they afford a salt in needles, which does not change in the air, is soluble in four or five times its weight of water, and does not swell in the fire. In a word, it is not alum. These characters have been given by M.

it has been found in many parts of France, particularly at Roanne in Forez, where they are very regular. I have given a full description of the feldt-spar found in the granites of Alençon, which is one of the most regular and beautiful I know. See my *Memoires de Chimie*. Note of the author.

* M. Daubenton has placed it among the scintillating stones. Three characters distinguish it from every other kind of stone. Its texture is spathose, it is chatoyant, and it gives fire with the steel. From these characters, this genus ought to contain more species than the late M. Bucquet attributed to it. M. Daubenton reckons the fishes eye, the avanturine, the Labrador stone, &c. of this genus. See his tables. Note of the author.

Bucquet,

Bucquet, who examined many of these stones. But as they are yet very little known, they may be placed after the clays.

Genus I. LAPIDES OLLARES, HARD.

Their texture is scarcely at all foliated; their appearance is greasy; they take but a bad polish.

Species.

1. Grey lapis ollaris from Sweden.
2. Greenish colubrine of Sweden.
3. Yellowish soap-stone of China.
4. Brilliant green; jade. The lapis nephriticus, and those of Otaheite, were varieties of jade according to M. Bucquet. We may observe that jade is very hard, and gives fire with the steel. It is doubtless after Pott, that M. Bucquet placed it among the lapides ollares.
5. Dirty green lapis ollares. Colubrine.
6. Serpentine. A stone of deep green, or blackish colour, with black spots or veins, like the skin of serpents. We have placed it at the end of the lapides ollares, on account of its aspect, though it seems to be a compound stone.

Genus II.

Genus II. TENDER LAPIDES OLLARES,
STEATITES OF SMECTITES.

They have a more soapy feel than the preceding. They are very easily cut ; they lather with water ; some kinds have a striking resemblance with soap.

Species.

1. White steatites, compact ; Briançon chalk.
2. Brilliant or glittering Briançon chalk. Venetian talc of the druggists.
3. White steatites from Norway.
4. Red marbled steatites from Norway.
5. Reddish steatites from Norway.
6. Green compact steatites from Norway.
7. Green and red steatites from Norway.
8. Green steatites, foliated ; tender colubrine from Norway.
9. Black steatites.
10. Grey and brilliant steatites, plum-bago, molybdena, and improperly black lead. This being pulverized, and made into a paste with isinglass, is inclosed in small wooden cylinders, which are cut to a point at

at the end, and used as crayons or pencils.*

Genus III. TALC.

It is composed of polished and glittering laminæ, of a jelly-like transparency, applied one on the other. It appears that these laminæ are sometimes crystallized in hexagons, or sections of six-sided prisms. By a violent fire it melts into a coloured glass.

Species.

1. Talc in large transparent plates; Muscovy glass.

* Since the death of M. Bucquet, and the first impression of this book, Messrs. Scheele, Grahn, and Hielm have made very successful researches into the nature of plumbago. They have discovered that this substance is a kind of sulphur formed, according to them, by the combination of the aerial or cretaceous acid with phlogiston. We shall give its history after that of sulphur. The same chemists, and especially M. Scheele, have made a proper distinction between molybdena and plumbago, which naturalists have, till lately, confounded together. Molybdena is regarded by Scheele as a compound of sulphur and a peculiar acid, which he called the acid of molybdena. (See the history of sulphur.) It is the plumbago which is used for crayons. Note of the author.

The English pencils are made by fixing or setting one or more slips or pieces of plumbago in a groove between two slips of cedar, which are then glued together. The inferior sort sold in the streets by Jews are the kind mentioned by the author. T.

2. Talc

2. Talc in very small silvery white spangles.

3. Talc in very small gold coloured spangles.

The two last mentioned are used as writing sand under the name of silver or gold dust.

4. Talc worn into the form of pebbles.

5. Talc in black spangles.

6. Talc in mixed brilliant spangles.

Genus IV. AMIANTHUS, ASBESTOS.

This genus of stones is formed of fibres or threads placed parallel to each other, or interlaced together like tissue; the fibres are either rigid or flexible, and differ from each other in thickness, length, and colour. The ancients wove them into a cloth, which was called incombustible linen, and used to envelope their dead when burned on the funeral pile. It served to retain and collect their ashes, &c.

By a violent fire amianthus is easily melted into a coloured opaque glass.

Species.

1. Asbestos, hard and grey, with parallel fibres; ligneous asbestos.

2. ———, hard and green in parallel fibres.

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3. Asbestos,

3. Asbestos, hard and green, with fibres in bundles.
4. ———, with diverging fibres.
5. ———, with soft fibres.
6. Amianthus, hard, with parallel greenish fibres.
7. ———, hard, with parallel white fibres.
8. ———, with white brilliant fibres in bundles.
9. ———, in hard bundles, yellowish.
10. ———, white and flexible.
11. ———, grey.
12. Mountain flesh.
13. Mountain leather.
14. Mountain cork.

SECTION II.

Compound Earths and Stones.

They are not distinguishable by the eye from those of the preceding section. As to their characters, they are formed of matter apparently homogeneous, almost always coloured, mostly opaque, but sometimes transparent, and most specimens are regularly crystallized. Their form and colour serve to distinguish the genera. They are all very fusible, and afford different kinds of glasses. Their fracture is sometimes vitreous, sometimes scaly. In these substances it is, that

that nature has combined earths, salts, and metals together.

M. Bucquet divided these stones into two orders. In the first were comprehended earths and stones, composed by water, to which he gave the characters proper to the products of that element. He divided this order into two genera; namely ochres, and zeolite. In the second, he placed schorl, macles, trap, azure stone, the fusible precious stones, volcanic crystals and glasses, and pumice stones. He regarded these eight kinds of stones as the products of fire. We have considered it as our duty to exhibit the ideas of this celebrated chemist; but as the distinctive characters of these two orders are not yet established on numerous and conclusive proofs, and as M. Bucquet himself proposed them as mere sketches, we shall here give the history of the several kinds in succession, without adhering to his method of division.

Genus I. OCHRES.

Ochres are less acted on by water than clays. They are friable, and soil the fingers; their colour is caused by metallic substances, almost always iron. When urged by fire, their colour becomes more intense. A violent heat melts them. They are used as pigments.

Species.

1. Yellow ochre.
2. Red ochre, blood colour.
3. Green ochre; earth of Verona.
4. Brown ochre; Umber.

Genus II. Zeolite.

Zeolite, first described by Cronstedt, is a stone composed of needles diverging from a centre. It neither gives fire with steel, nor effervesces with acids. Exposed to the action of fire it swells up, and affords a white glass resembling enamel. By distillation it affords much water. The residue contains, according to Bergman, filiceous, argillaceous, and calcareous earths. M. Bucquet, who likewise made the analysis of this substance, affirms, that he found very little filiceous earth, and a peculiar earth, which is neither argillaceous nor calcareous, but forms with the vitriolic acid a crystallizable salt in small shining plates, resembling sedative salt, which he has thought proper to call zeolitic earth. These two earths are crystallizable together by the assistance of water, which makes more than one eighth of the whole composition. M. Bucquet obtained one drachm and a half of water from an ounce of the white zeolite, of

of the island of Ferro.* The property of forming a jelly with the different acids is not peculiar to this substance, but is common to the azure stone, tin, and to several ores of iron, &c. Its origin and formation are unknown; but it is abundantly found among the products of volcanos. It is very plentiful in the island of Ferro. We are acquainted with six sorts.

Species.

1. White zeolite in transparent fascies.
2. White zeolite in compact fascies.
3. Red zeolite.
4. Green zeolite.
5. Blue zeolite.

The red, green, and blue have not been examined.†

Genus III. SCHORL.

Schorl is a stone of a dark colour, violet, black, or green, rarely white, moderately brittle, and giving fire with steel. It readily melts into a black opaque glass. According to M. Bucquet, it contained clay and iron in combination. Bubbles have been ob-

* Mémoires des Savans étrangers; tom ix. page 576.

† M. Pelletier, the pupil of M. D'Arcet, has given (Journal de Physique, 1782, p. 420.) a memoir on the analysis of the zeolite of Ferro. By very accurate experiments he found that 100 grains of this stone contain 20 of pure clay, 8 of lime, 50 of siliceous earth, and 22 of water. Note of the author.

served in the internal part of schorls, similar to those in the flags at glass-houses.

Its origin is not well known. Some persons regard it as a volcanic product, because it is frequently met with in places which have been burned; but it is likewise found among matters formed by water.

Species.

1. Violet, crystallized schorl.
2. Violet, in fibrous masses.
3. Black, in prisms of four, six, eight, or nine sides; with pyramids of two, three, or four faces, like the violet schorl.
4. Black schorl in masses.
5. Green schorl in lamellated masses.
6. White bluish schorl.
7. Electric schorl of a reddish yellow, tourmaline.

Genus IV. MACLES.

By this name we understand certain prismatic opaque stones, of a dirty appearance, often regularly formed. Their analysis made by M. Bucquet, shews that they approach the nature of schorls. They are composed of iron and clay.

Species.

1. Tetrahedral macle, whose section shews the figure of a cross. It is found in a kind of hard, deep blue

blue shistus of Britany ; it is very adhesive ; and very brittle. When broken, two blueish lines are seen on its transverse section, intersecting each other in the middle, and forming a cross. Sometimes the middle of the prism appears to be filled with a matter fimilar to that of the gangue.

2. Cross-stones. Hexahedral prisms, articulated and crossed in the middle like the arms of a cross. They are found in the leaves of yellow mica. The two branches scarcely ever cross each other at right angles.

Genus V. Trap.

Trap is a hard stone of a fine grain, of a foliated fracture, with angular indentations like steps. It is of a deep blackish green, often inclining to the colour of ochre : sufficiently hard to give fire with steel, and affords a blackish glass in the fire. It is always covered with a kind of matter less hard than its own substance. Its component parts, according to M. Bucquet, are clay and iron, the latter being in the proportion of twenty-five pounds per quintal ; so that it may be ranked among iron ores. M. Daubenton considers it as a shistus containing quartz in sand. We know but of one

kind of trap, which is that above described.

Genus VI. AZURE STONE; LAPIS LAZULI.

Its colour, the fineness of its grain, the analysis, which shews that this stone contains iron, are reasons for placing this immediately after the foregoing. There are three species.

1. Oriental azure stone.
2. Azure stone of a pale blue, frequently inclining to purple.
3. Armenian stone; spotted with white and pale blue.

The beautiful blue called ultramarine, which is used by painters, and is one of the most unchangeable we are acquainted with, is prepared from this stone.

Genus VII. FUSIBLE CRYSTALS CALLED GEMS.

The chemical differences observed between the several kinds of precious stones or gems, induced M. Bucquet to separate them from each other, and to class each in the order or section to which it seemed to belong. Those which are ranked in this place are evidently of a compound nature. M. Bergman found them to contain many substances, such as
filiceous

siliceous earth, clay, lime and iron. They are all fusible, and of a laminated structure. Their fracture is lamellated.

Species.

1. Aqua-marine.
2. Emeralds.
3. Chrysolite.
4. Ruby.
5. Bohemian garnet.
6. Garnet.

Genus VIII. Volcanic Crystals.

In this genus M. Bucquet comprehended all regular formed stones, transparent and coloured like the gems, but which have neither their hardness nor brilliancy. They are found in cavities lined with small brilliant particles of the same nature agglutinated together. They are met with in the neighbourhood of volcanos, but it is not known whether they are formed by fire. We admit three species.

Species,

1. Volcanic chrysolite ; polyhedral crystals of a golden green.
2. Volcanic hyacinth ; polyhedral crystals of orange yellow.
3. Volcanic garnets. They greatly resemble single garnets, but they are irregular and scattered among, or on the surface of, brilliant lavas,

vas, together with the two foregoing.

Genus IX. Pumice Stones.

Most of the pumice stones appear to consist of an assemblage of vitreous fibres, like threads wound on a clue. Their substance is a true combination of various matters fused by volcanic fires.

Pumice stones may be distinguished into four kinds, each of which has many varieties.

Species.

1. White fibrous pumice stone.
2. Coloured fibrous pumice stone.
3. Cellular and light pumice stones.
4. Cellular and compact pumice stone.

Genus X. VOLCANIC GLASS.

The glasses melted and ejected by volcanos are formed of earthy and saline matters, coloured by iron, or other metallic matters. They are true chemical combinations performed by nature in the dry way.

Species.

1. Cellular greenish glass.
2. Blackish glass; cellular, or in agglutinated fibres.
3. Beautiful black transparent glass, Iceland agate, lapis obsidianus of the ancients.

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SECTION III.

Mixed Earths and Stones.

It is very easy to observe the leading character of the stones of this section, as mere inspection is sufficient to shew the different matters which compose them; especially if they be properly compared with the varieties of the preceding sections. We have already remarked, that mechanical separation of their several parts is first required before the chemical analysis can be undertaken. If these mixed stones be exposed intire to the action of fire, they melt with more or less facility into glasses of different colours and appearance, according to the nature of the parts which composed the mixture.

They appear to have been formed by the junction of the different substances we see; and this junction must have been made either by means of water or fire. This last consideration engaged M. Bucquet to divide this section into two orders like the foregoing. The first order comprehends the mixed stones formed by water; and the second, such as have been composed by fire. This division being founded on a much greater number of facts than the preceding, induces us to admit it with much more confidence.

Order

Order I. Earths and Stones of a mixed Nature, formed by Water.

Genus I. Petro-filex.

By this name naturalists denote a stone of an intermediate hardness between the softer stones, and those of the siliceous order. M. Daubenton has placed it among the vitreous stones, because it gives sparks with the steel, and its fracture is vitreous, though rather scaly. Petro-filex has a semi-transparency resembling wax. It is dull, and not at all shining, but rather of the aspect or defective kind of polish which tallow usually has. Its grain is fine, and very close. It is found in very large masses, and often in beds or strata of different shades, lying above each other. M. Bucquet gives us its chemical character; that of melting by fire into an opaque glass. Its mixture is very far from being as evident to inspection, as that of the following genera. It seems to have the same characters as the compound stones,* and

* It is necessary to observe that these characters, founded on the action of fire on stones, are established by experiments made by the Duc de la Rochefoucauld, and by M. Bucquet, in an excellent melting furnace constructed for that purpose in the laboratory which the distinguished encourager of the sciences here mentioned has devoted to every kind of research that may tend to the advancement of

and is, for that reason, placed at the head of this third section. It serves, as it were, as a connecting link between the two.

The form of its beds, that matters it frequently contains, and especially the masses of it, which are placed in the bowels of the earth, shew that it is formed by means of water.

Species.

1. Grey petro-filex.
2. Reddish.
3. Greenish.
4. Brown.
5. Black.
6. Spotted.
7. Veined.

Genus II. PUDDING STONE.

Pudding stone is a mixture of flints connected by a cement of a different nature. This cement is either of the nature of free-stone, or argillaceous, or ochreous. It is sometimes hard, and resembles filex.

It is not at all doubtful, but its formation is effected by water. It is always found on the sea coasts, or in places which have been covered by water, and afterwards deserted by that element.

of chemistry. I have examined most of those results, which will doubtless be communicated to the learned world. This communication will confirm the valuable series of experiments made by M. D'Arcet, with the addition of many facts serving to establish the chemical characters proposed by M. Bucquet, to be used in the classing of stones. Note of the author.

Species,

Species.

1. Sandy pudding-stone.
2. Ochreous.
3. Argillaceous.
4. Siliceous.
5. Agatified; susceptible of the finest polish.

Genus III. GRANITE.

Granite is formed of three stony matters in fragments of greater or less magnitude united together. These three substances are quartz, feldt-spar, and mica.

It gives fire with steel on account of the quartz and feldt-spar it contains; its fracture is irregular, and very coarse grained; it is fusible, but in different degrees, according to the respective quantities of the matters which compose it. It takes a polish more or less bright, according to the fineness of its grain, and the hardness of the principles which enter into its composition. Some specimens change by exposure to the air. This last phenomenon has served to distinguish the ancient from the modern granites. The species of granite have been greatly multiplied.* They may, however, be reduced to the following:

* Modern philosophers have paid great attention to the natural history of granite. M. de Saussure has given much new and important information on this subject in his *Voyage des Alpes*. All granites are not formed by the mixture of the three stones mentioned in the text. There are some which contain

Species.

1. White granite.
2. Grey.
3. Red.
4. Brown.
5. Green.
6. Black.
7. Dull and friable; altered by exposure to air.

Genus IV. PORPHYRY.

Porphyry is a stone covered with spots in a ground of a red or other colour. It gives many sparks with the steel.

It differs from granite by its greater hardness, and its being susceptible of a much more lively polish. It appears to be formed of feldspar and schorl united by a quartzose cement.

The cement or paste, which forms the basis of porphyry, is of a very fine and close grain. The different fragments, which are bedded in this ground, are in general much smaller than those of granite. This stone is fusible, and affords a coloured glass. All the species of porphyry may be reduced to the seven following:

Species.

1. Red porphyry, with large spots.
2. —————, with small spots.

tain schorl instead of mica; others contain both schorl and mica. The mixture of quartz and feldspar only is called granitin; and the stone composed of quartz and schorl is called granitello. See De Saussure's *Voyages dans les Alpes*.
Note of the author.

3. Green

3. Green porphyry, with large spots.
4. —————, with small spots.
5. Black porphyry, with large spots.
6. —————, with small spots.
7. Coarse porphyry of a dirty red, approaching to the nature of sandstone.

Genus V. OPHITES OR SERPENTINE.

Pliny gives the name of ophites to stones spotted like the skins of serpents. M. Bucquet considered them as species of porphyry; but harder, more ancient, and of a mixture much more intimately combined. The name of serpentine, or hard serpentine, has been given to them. On comparing this stone with porphyry, it is seen that serpentine, as well as porphyry, is composed of a quartzose paste, together with feldt-spar and schorl, but that the feldt-spar in the former is in large rhomboidal fragments, while it is very small in the porphyry.

Serpentine gives sparks with steel. Its fracture is fine, and rather scaly. It melts in the fire.

The following are the principal species of serpentine we have seen.

Species.

1. Ophites of a deep green colour, with large white spots.
2. Ophites of a deep green colour, with oblong pale green spots.
3. Ophites

3. Ophites similar to the foregoing, but with very small, and scarcely perceptible spots. Many savage nations cut them into coins. They have been called thunder-stones.
4. Ophites of a brown colour, with irregular oblong spots of a rose coloured white.

The origin of ophites is very obscure. It is not well known whether they are the product of water, or of fire. As they have some analogy with porphyry, we have placed them after that stone.

Order II. Earths and Stones of a mixed Nature formed by Fire.

CONTINUATION OF THE VOLCANIC PRODUCTS.

There is no dispute concerning the origin of substances which compose this order, since they are never found but in the neighbourhood of volcanos, or in places where volcanos have formerly existed: besides which, they exhibit all the characters of products of fire. By joining the genera of this order with those described among the compound stones, a complete series of volcanic products will be had.

We shall not comprehend under the name of volcanic products all the stones or earths

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found

found in the neighbourhood of volcanos, which are not at all altered by fire; as is the case with the greater part of the stones we have already described, especially granite, clays, &c. as well as many saline substances, together with calcined, melted, sublimed, or vitrified matters. It would be an useless repetition to take notice of their history in this place. We shall elsewhere take notice of their existence in the neighbourhood of volcanos, and the changes produced in them by the subterraneous fires.

Genus I. VOLCANIC ASHES.

The name of volcanic ashes has been improperly given to certain pulverulent earthy matters found near volcanos. They appear to owe their origin either to the substances mixed and thrown out by volcanos, or to lavas altered by the contact of air and water. M. Bucquet considered them as combinations of clay and iron. They frequently obey the magnet. We are acquainted with two species.

Species.

1. Rapillo; a pulverulent matter of a blackish grey, found near the craters of volcanos.

Rapillo contains garnets and schorls, whose form is distinguishable, though their angles have been softened

softened and encrusted apparently by some matter in fusion.

2. **Puzzolana.** This substance is named from the town of Puzzoli, where it was very anciently made use of. It is an argillaceous earth, charged with iron, and of different colours, according to the state of the metal. It is found of a grey, yellow, red, brown, or black colour. By fire it melts into a black enamel. The great utility of this substance consists in its forming a kind of mortar, which has the property of becoming hard in water. M. Faujas de St. Fond has found it in Vivarais. He thinks that these earths are formed by the alteration and destruction of the porous lavas, and even of the basaltés. This philosopher, in his researches concerning puzzolana, has given a detail of the processes for constructing edifices both in the air and under water with this substance.

Genus II. LAVAS.

This name is given to the melted and semi-vitrified matter of volcanos. They most commonly flow down the sides of moun-

tains, whose internal parts are on fire, and form rivers of burning matter, which sometimes flow to prodigious distances, to the destruction of every thing in their way. Their heat and mass are so considerable, that they are several years in cooling. During this period, they crack and separate into masses, which are sometimes regularly formed. Such appears to have been the origin of basaltes. A great variety of these stones are found in cabinets of natural history. They are in general composed of a paste of a grey colour, more or less deep, with great varieties of texture and hardness, in which are bedded crystals, or irregular fragments of schorl, garnet, glass, zeolite, &c. constituting a true mixture. It is impossible to give any general character of lavas, as they all differ in their grain, consistence, hardness, colour, mixture, &c. In general they are very fusible, and afford a kind of black enamel, similar to the glass of volcanos. M. Cadet has found them to contain clay, iron, copper, and quartz. Bergman thinks them to be composed of siliceous, argillaceous, and calcareous earths, with iron. Many, and more especially the compact lavas, have the property of acting on the magnetic needle.

Species.

1. Soft lava of various colours, with crystals of black schorl.
2. Soft lava of various colours, with crystals of green schorl.
3. Soft

3. Soft lava of various colours, with crystals of white schorl.
4. Reddish lava, with blackish crystals.
5. Yellowish and saline lava.
6. Soft lava with crystals of garnet.
7. Chatoyant and porous lava.
8. Porous, grey lava.
9. Soft lava, blackish, with white crystals.
10. Grey lava, rather compact, interspersed with opake, dodecahedral crystals, or garnets altered by fire.
11. Ancient lava, very compact, of a blackish grey, with spots of a deeper colour.

Genus III. BASALTES.

The descriptions given by naturalists of basaltes, are very far from being exact. Many confound schorls and grenates with the true basaltes, and no writer has given a good definition of the word. Some regard this substance as a volcanic product; others have supposed them to be formed by water. We think it proper, in consequence of the valuable observations of Messrs. Desmarets and Faujas de Saint Fond, to adopt the former opinion.

We may assume the following as the distinctive characters of basaltes. A regular

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form;

form; hardness sufficient to give fire with the steel; cinereous grey colour inclining to black, and a manifest mixture of schorl or small vitrified fragments, usually of a deeper colour than the ground. The basaltes are fusible.

Some stones of this kind are of enormous magnitude, and exist in very considerable masses, whose formation seems to have been effected in times of the remotest antiquity. Such are, 1. The giants causeway, in the county of Antrim, in Ireland. 2. The rock of Pereneire, near Saint-Sandoux, in Auvergne, well described by M. Desmarests. There are others regularly crystallized in small prisms of three, four, or five sides, &c. Their figure, magnitude, and disposition is exceedingly various.

In general, these stones are ranged symmetrically, one beside another. Their analysis does not appear to have been yet made with sufficient accuracy to authorize any decided account of their nature. They seem to be nothing else but lavas, apparently crystallized in consequence of the cracks formed in them in every direction during their cooling. The singular varieties they offer, and their arrangement, seem to give much force to this opinion. Water seems to have insinuated itself into these clefts, and to have there deposited various earths, at the same time that it has produced some alteration

ration on the correspondent surfaces of the basaltcs. This is apparently the cause of the yellow or brown crusts which seem to envelope them.

Species.

1. Basaltcs in very long polygonal prisms, without regular pyramids.
2. Basaltcs in short prisms, truncated with three, four, five, or seven faces.
3. Basaltcs in short polygonal prisms, terminated by a concavity above, and a convexity below. Articulated basaltcs.
4. Small quadrangular, triangular, &c. Basaltcs; formed by the fractures of the larger, and grouped with them.

Genus IV. SCORIÆ OF LAVAS.

The melted matter which constitutes lavas, is a mixture of many heterogeneous substances, differing in density and weight. During its cooling these separate in the order of their specific gravities. The scoriæ of lavas are bodies frequently of a spongy nature, which not having suffered as complete a fusion as the lava itself, rise above it by their comparative levity. In other respects they seem to be of the same nature, except that their principles are less perfectly mixed together.

together. Crystals of schorl and granite are found in them as well as in the lavas themselves.

Species.

1. Heavy volcanic scoriæ of a compact texture.
2. Black and cellular volcanic scoriæ.
3. Black and spongy volcanic scoriæ.
4. Black volcanic scoriæ, with twisted fibres.
5. Yellow and ochraceous volcanic scoriæ.
6. Reddish volcanic scoriæ.

The two last have been manifestly altered by the contact of air, water, and acid vapors.

Such was the method in which the late M. Bucquet thought proper to class earths and stones in 1777 and 1778. Mineralogical chemistry has been greatly improved since that time. The analysis of stones has been made in almost every chemical laboratory. Messrs. Bayen, D'Arcet, Monnet, De Morveau, Sage, Mongez, Pelletier, in France; Scheele and Bergman, in Sweden; Achard, Bindheim, and Hupsch, at Berlin; Woulfe, Withering, and Kirwan, in England, have examined a great number of stones and earths, and in consequence of these numerous analyses, the classification of these substances has suffered great changes; and two of the above-mentioned chemists have thought proper to publish systems of mineralogy,

ralogy, founded on the principles of bodies. But they have pursued a very different course from that of M. Bucquet, whose aim was to associate the external characters with the chemical properties. Messrs. Bergman and Kirwan have paid scarcely any regard to the physical qualities in the classification of earths and stones. The nature, quantity, and proportion of their constituent parts have determined them in their methodical distribution. Their system, though very useful in the promotion of chemical knowledge, cannot answer the purpose of distinguishing stones by their aspect and sensible characters. It therefore appeared necessary to prefix to those systems a natural method, as we have here done, with the intention, that each should illustrate the other to the advantage of such as undertake the study of minerals.

§ 11. The Chemical Distribution of Earths and Stones, according to Bergman.*

After shewing that the external characters are not sufficient to distinguish minerals from each other, though they may be of great assistance when judiciously chosen,

* The author in a note observes, that he has made use of the French edition of Bergman's *Sciagraphia Regni Mineralis*, translated by Mongez. The English reader may recur to a translation of this excellent small work, published in London by Dr. W. Withering.

Bergman

Bergman establishes his principal divisions of classes and genera on the composition and internal characters of the bodies. The principle, which is either the most abundant or the most active, in any mineral, is made use of as a guide in its distribution. He divides all minerals or fossils into four classes, namely, salts, earths, bitumens, and metals. We shall only take notice of the earths in this place.

Bergman admits of five earths, simple and different from each other; namely, ponderous earth, lime, magnesia, clay, and filicious earth.*

He first examines each of these earths in a state of purity, though they are never found so in nature. He remarks that these five earths combined together may afford twenty species, viz. ten combinations of two; six of three; three of four; and one of the whole five. But as he ranks among the earths such of their combinations with acids as are not soluble in one thousand times their weight of boiling

* Among these five earths, three have evident saline properties; namely, the ponderous earth, lime, and magnesia; and for that reason we shall give their history in the second part of our work. Bergman, whose intention was to divide stones according to their principles, was necessitated to rank them among the earths, because they are often united with each other. Many substances which this illustrious chemist has reckoned among the earths, are salts in our method. The Author.

water,

water, the number of species is greater on this account. Besides which, two earthy compounds consisting of like principles, may differ greatly in the proportion of these principles, and therefore have very distinct and different properties belonging to their respective combinations. Such are the grounds of distinction of the species admitted by Bergman, and by his commentator M. l'Abbé Mongez, who has made large additions to the labours of the Swedish chemist. Here follows the species of each primitive earth according to this method.

Ponderous Earth.

Species I. Pure ponderous earth; it does not exist in nature, and is obtained by the decomposition of the ponderous spar, as we shall see hereafter.

Species II. Aerated ponderous earth, or the combination of the ponderous earth with the aerial acid.

Species III. Vitriolated ponderous earth; ponderous spar; or the combination of the vitriolic acid with ponderous earth. This substance is abundantly found in mines. The Bolonian stone is a variety of this.

Species IV. Vitriolated ponderous earth, penetrated

penetrated with petroleum, mixed with filenite, alum and filiceous earth; hepatic stone of Cronstedt. This substance is spathose and brilliant; yellow, brown, or black; its odour is very strong, and it does not effervesce with acids. A centenary of this natural compound contains, according to the analysis of Bergman, 33 parts of filiceous earth, 29 of pure ponderous earth, and 5 of clay, besides lime, water, and vitriolic acid.

Lime.

Species I. Pure lime, or quick lime. Bergman did not know of its existence in nature.

Species II. Aerated lime. Chalk, or calcareous earth. The combination of lime with the aerial acid. It is rarely pure. It often contains the marine salt of magnesia, calcareous marine salt, clay, filiceous earth or iron. Within, or at the surface of the earth, it constitutes lac lunæ, stony icicles, calcareous stones, marbles, calcareous spars, concretions, or stalactites, &c.

Species III. Aerated lime impregnated with bitumen or petroleum; swine-stone.

It

It is found in France at Villers-Cotterets, at Plombieres, at Ingrande in Anjou, at Rattwyk in Dalecarlia, at Kineculle in Westrogothland, at Krasnasele in Ingermania, in Portugal, in Sweden, &c. It emits a fetid smell, when it is rubbed or heated; sometimes the odour resembles that of the urine of cats; and for this reason it has been called *lapis felinus* by some author. With acids it effervesces; in the fire it decrepitates, and loses its odour and colour. When distilled in large quantities, it affords, 1. A fetid liquor, which reddens syrop of violets, and effervesces with acids. 2. A black strong smelling oil, resembling that of pit coal. 3. Concrete volatile alkali. The residue contains a little marine salt. This substance owes its distinguishing properties to the bitumen it contains.

Species IV. Fluorated lime. Fluor mineral, or vitreous spar, combination of lime, with the sparry or fluor acid mixed with clay, siliceous earth, or a small quantity of marine acid.

Species V. Lime saturated with a peculiar acid,

acid, probably metallic.* Heavy stone, tungsten of the Swedes. This is the heaviest of all stones. It is found in small yellow or red grains, in the mines of Bastnas, near Ritterhutte in Westmanland; and also of a spathose, brilliant, and whitish appearance at Marienburgh, and at Altenburg in Saxony. It is often compounded with the white tin ore. It resists the fire, and only vitrifies at the surface. It is not soluble in boiling water. The vitriolic acid seizes the lime. The nitrous acid, being added to a solution of this stone in volatile alkali, precipitates a white powder, which is the peculiar acid discovered by Scheele.† The tungsten may be distinguished from every other stone, by pouring the nitrous or marine acid upon it in powder, which last becomes of a beautiful yellow on being slightly heated. (See the Journal de Physique, 1783, vol. 22.)

* Since found to be so. See Scheele's Essays, and De Luyart's on wolfram, both translated into English, and published in London. T.

† De Luyart's have shewn that this is a triple salt, consisting of wolfram-calx, volatile alkali, and nitrous acid. It is soluble in water, and has acid properties. The pure calx, though not evidently soluble in water, resembles acids in its affinities with alkali and lime, and its insolubility in acids. T.

Species

Species VI. Aerated lime contaminated† with a small quantity of muriatic magnesia, or marine salt of magnesia.

Species VII. Aerated lime contaminated with clay. False marle.

Species VIII. Aerated lime, contaminated with siliceous earth. Some calcareous stones used by masons, and certain marbles, are observed to give fire with the steel, by reason of the fragments of quartz they contain.

Species IX. Aerated lime, contaminated with argillaceous and siliceous earths. Perfect marle.

Species X. Aerated lime, contaminated with iron and magnesia; false white iron ore; pulverulent and black, or hard and red, or whitish. The mines of Hallefors afford these varieties.

Magnesia.

Species I. Pure magnesia; always produced by art.

Species II. Aerated magnesia; found dis-

† The word *contaminated* (*inquinatus*) is used by Bergman to denote a simple mixture of two or more earths, without a true combination. We have therefore substituted occasionally the word *mixed* in its place. The author.

solved in waters impregnated with aerial acid.

Species III. Aerated magnesia, mixed with filiceous earth. It is scintillant and effervescent.

Species IV. Magnesia intimately combined with filiceous earth and clay; steatites, Briançon chalk, soap stone, lapis ollaris, serpentine, lapis nephriticus.

Species V. Magnesia united to a considerable portion of filiceous earth with a smaller quantity of calcareous and argillaceous earths, and contaminated by calx of iron. Mountain cork; mountain leather; amianthus. Bergman found in a centenary of amianthus, 64 parts of filiceous earth, 18.6 of magnesia, 6.9 of lime, 6 of vitriolated ponderous earth, 3.3 of clay, and 1.2 of calx of iron: and the same quantity of asbestos afforded 67 parts filix, 16.8 of magnesia, 6 of clay, 6 of lime, and 4.2 of calx of iron.

Species VI. Magnesia mixed with argillaceous and filiceous earths and pyrites; a species of alum ore described and analysed by M. Monnet (Syft. de Minéralogie, genre 9. pag. 161.)

Species VII. Magnesia mixed with argillaceous

aceous and siliceous earths, together with petroleum and pyrites; magnesian aluminous shistus.

Clay.

Species I. Pure clay; it is precipitated from alum by the aerated volatile alkali.

Species II. Clay mixed with siliceous earth. Porcelain clay, kaolin of the Chinese. Solid clay of Saint-Iriez in Limoufin, of Japan and of Saxony. Pulverulent clay of Westmanland, of Boserup, and of China. These earths are often mixed with mica.

The clays used in the more ordinary kinds of pottery are coarser, but of the same nature.

Species III. Clay mixed with siliceous earth and iron. Boles or bolar earths, grey, yellow, red, brown, or black. They are washed, in order to make the sealed earths. The common clays of a green, blue, and red colour, are of this species.

Species IV. Clay mixed with siliceous and calcareous earth. Argillaceous marle; tobacco-pipe clay; agaric mineral or fossil.

Species V. Clay mixed with siliceous and magnesian earth. Lemnian earth;

fuller's earth ; soap-rock ; smectites. Bergman has obtained from the Lemnian earth, the Hampshire clay, and the fuller's earth of England, a large portion of siliceous earth, about $\frac{1}{2}$ of clay and aerated lime, and $\frac{1}{10}$ of aerated magnesia and calx of iron. He gives the generic name of lithomarga to these earths.

Species VI. Clay contaminated with sulphur and vegetable alkali. Alum ore of Tolfa and Solfatara. Bergman considers it as a volcanic product.

Species VII. Clay mixed with siliceous earth, pyrites, and petroleum. Aluminous shiftus. It is found in Italy, in the province of Liege, in Sweden, and in Jemtland. The black crayons, such as those from Bechel near Seez in Normandy, and the ampelites, are of this species. The tripolis are an aluminous shiftus more or less burnt. Such are those of Poligné in Normandy, and of Menat in Auvergne.

M. Mongez reckons in this species the shifti, which contain clay in a large proportion, and more or less of siliceous earth and bitumen. The greater number are mixed with calcareous earth, and effervesce with acids. The proportions of these principles vary greatly in the different shifti. There are

are some of so bituminous a nature, that they burn with a flame; others are loaded with pyrites, and effervesce in the air; and others are very hard, and give fire with the steel. M. Mongez admits five varieties. 1. The hard argillaceous schistus, or writing slate. 2. The soft argillaceous schistus, or roof slate. 3. The soft siliceous schistus, or polishing stone for metals. 4. The hard siliceous schistus, or stone for setting razors. 5. The hard calcareous schistus, which makes a bad lime; as that of Allevard in Dauphiny.

Species VIII. Clay combined with less than half its weight of siliceous earth, a small portion of aerated lime and calx of iron; crystal gems. The happy researches of Bergman into the nature of gems, whose excessive hardness and immutability seem to defend them from the operations necessary to their chemical analysis, have been confirmed by the labours of Margraaf, Gerhard, and Achard. Here follows the results of Bergman's analysis of five crystal gems, which are varieties of the species we are now attending to:

	Clay.	Silex.	Lime.	Iron.
Oriental emerald contains	60	24	8	6
Oriental sapphire	58	35	5	2
Saxon topaz —	46	39	8	6
			Oriental	

	Clay.	Silex.	Lime.	Iron.
Oriental hyacinth	40	25	20	13
Oriental ruby —	40	39	9	10

The methods which this celebrated chemist has put in practice in order to obtain a knowledge of the component principles of these stones, are very ingenious, and at the same time very simple. (See Bergman's *Essays in English*, London, 1784.)

Species IX. Clay combined with filiceous earth, composing more than half of the total, weight with a very small quantity of aerated lime and iron, garnet; schorl; tourmalin. The proportion of iron varies in these stones. (See the *Analysis of the Tourmalin of Tyrol*, by M. Muller; *Journal de Physique*, vol. xv. p. 182. ann. 1780.)

Species X. Clay slightly united with filiceous earth, composing the half of the weight, and sometimes more, together with a small proportion of lime; zeolite. M. Mongez considers the azure stone, lapis lazuli, as a zeolite. M. Margraaf has found a small quantity of gypsum ready formed in the lapis lazuli.

Species XI. Clay united to much filiceous earth, and a little magnesia; talc; mica. The proportion of the

the principles which compose this stone have not been exactly ascertained.

Siliceous Earth.

Species I. Pure filiceous earth. It is prepared by fusing clear quartz with four parts of fixed alkali, dissolving the whole in distilled water, and precipitating the earth by an acid. This earth is to be well washed and dried.

Species II. Siliceous earth united to a very small proportion of calcareous and argillaceous earth. Rock crystal with its varieties; quartz and its varieties; grit-stone and its varieties.

Species III. Siliceous earth united with argillaceous earth. Calcedony hydrophanes, or oculus mundi; this contains more clay than filiceous earth, according to M. Gerhard of Berlin. Opal; M. Mongez considers as varieties of this stone, the cat's eye, the fish's eye, and the girasol; to these three sorts of stones he adds the agate, and its varieties; the cacholong, the cornelian, the sardonix, the gunflint, the jade. Their analysis has

not yet been made with much exactness.

Species IV. Siliceous earth united to a very martial clay ; jasper. M. Mongez reckons the sinople as a variety of jasper.

Species V. Siliceous earth rendered heavy by martial earth. False jasper. M. Mongez calls this stone metallic quartz. He distinguishes it into the black coloured by iron, and the red coloured by copper.

Species VI. Siliceous earth united to argillaceous earth, and a small portion of lime ; petrosilex. This stone sometimes gives sparks with the steel, and effervesces with acids ; it melts in a strong fire.

Species VII. Siliceous earth united to clay, and a small portion of magnesia ; feldt-spar. It changes colour in the fire, and melts. It does not become decomposed by air ; it gives sparks with the steel, and breaks easily.

Species VIII. Siliceous earth united to magnesia, aerated and fluorated lime, with the calces of iron and of copper. Prase, chrysoprase. It is from the analysis of M. Achard, that Bergman describes the composition of this stone.

I. A P-

I. APPENDIX.

Bergman, in his first appendix, treats of minerals united, or mechanically mixed with each other, in such a manner, as that the parts may be distinguished by the eye. We shall here mention only the mixtures of earths. Such are the stones called rocks, *saxa*. M. Mongez distinguishes these stones or rocks into two genera. 1. Such as have not their parts united by means of any cement, but adhering simply by juxta position, being formed by various fragments agglutinated together. He distinguishes them into three species, granite, gneis of Saxony, and hornstone. 2. The mixed stones, whose parts are encrusted in a common cement, as is the case in four kinds, namely, porphyry, ophi-tes or serpentine, breccias and puddingstone. We shall, in this place, exhibit the varieties of these stones admitted by this naturalist.

I. GRANITE. It is formed of quartz, feldt-spar, mica, schorl, and steatites, mixed in different proportions, two and two, three and three, or four and four; the quartz always constitutes the base.

Variety I. Granite of two substances;
granitin.

A. Quartz and feldt spar.

B. Quartz and schorl.

X 4

C. Quartz

C. Quartz and mica.

D. Quartz and steatites.

Variety II. Granite of three substances.

A. Quartz, feldt-spar and mica. It is the most common, the most abundant, and the most varied of any.

B. Quartz, mica, and schorl.

C. Quartz, schorl, and steatites.

Variety III. Granite of four substances.

A. Quartz, feldt-spar, schorl, and mica.

B. Quartz, feldt-spar, schorl, and steatites.

II. GNEIS. Gneis is a mixture of quartz in grains, and mica in greater or less abundance, with much clay, or steatites which constitutes the base. This stone is foliated like shistus. It is subject to alteration and decomposition in the air, in consequence of the humidity which the clay absorbs. The Alps in Dauphiny contain many varieties of gneis.

III. HORN-STONE. This stone is composed of very minute parts, among which brilliant specks of mica may be distinguished. It has an earthy aspect, and when moistened, has an argillaceous smell. In the fire it hardens like clays, and melts into a blackish scoria, or black glass, if the heat be intense. Its colours are various. M. Mongez considers the trap of the Swedes as a variety of the horn-stone.

IV. PORPHYRY seems to consist of a hard and fine paste, of the nature of red jasper, which

which envelopes grains either crystalline, or irregularly shaped, of quartz, of white or reddish feldt-spar, and sometimes green or black schorl.

V. OPHITES. The ophites or hard serpentine, is a species of porphyry, whose cement is green, and the spots of a greenish white. These are usually longish in the ophites, while they are square or rhomboidal in the porphyry. The thunder-stone is a variety of this species.

VI. BRECCIAS (from the Italian word denoting fragment). This is a mixed stone of an origin greatly posterior to the preceding. It is formed by the destruction of the primitive mountains, and by irregular and worn pieces of flint, &c. united by one common cement. M. Mongez confounds the pudding-stones with the breccias. He gives a compound name to the latter, which indicates the nature of their fragments, and the cement which unites them. He distinguishes eight varieties. The calcareous breccia, which is the breccia properly so called, and the lumachello; the filiceo-filiceous breccia, or the pudding-stone;* the breccia with a calcareous cement, and fragments of the calcareous and filiceous genus; the breccia with filiceous cement, and fragments of the

* According to this nomenclature, the first word expresses the nature of its cement, and the second that of its fragments. The author.

calcareous and siliceous genus ; the arenario-siliceous breccia, such as the grison of Chartres ; the breccia with cement and fragments of jasper ; the breccia with cement and fragments of porphyry ; and the volcanic breccia.

II. APPENDIX.

Volcanic Products.

M. Mongez divides the volcanic products, after Bergman, into such as have been formed by fire, and such as owe their origin to water. The latter are nothing more than such earthy substances, as have been dissolved and suspended in water, and afterwards deposited in the neighbourhood, and among the products of volcanos ; such are the calcareous and siliceous incrustations, as well as the zeolites frequently found in volcanic productions.

M. Mongez divides the true volcanic products into three orders. 1. Earthy substances very little changed by the fire ; as calcareous matters, clays, granites, hyacinths, schorls, and mica. 2. Earthy substances calcined and burned ; as the volcanic ashes, or the rapillo and puzzolana, the tufa, the peperino of the Italians, the pumice stone, and the white earth which covers the solfatara. 3. Earthy substances melted, or
lavas,

lavas, of which he admits several species; spongy, compact, and stalactilical lavas, and volcanic glafs. To these divisions, he adds the earthy volcanic products of uncertain origin. In this order he particularly ranks the garnets, the volcanic schorl, and especially the basaltes, which he thinks are masses of trapp softened by the humid vapours of volcanos, and afterwards slowly dried when the vapours have ceased.

§ III. Chemical Classification of Earths and Stones, by Mr. Kirwan.

M. Kirwan, a celebrated chemist of London, published in 1784, a mineralogical work, in which he classes all the bodies of the mineral kingdom according to their chemical properties or combinations. The earths and stones are ranked in his first part. After having given as the characters of these substances, insipidity, dryness, brittleness, incombustibility, and insolubility in less than one thousand times their weight of water; like Bergman, he admits five genera of simple earths, the calcareous earth, ponderous earth, or barytes; magnesia, or muriatic earth; argillaceous earth, and siliceous earth. Under these genera he places, according to the chemical analysis, all the known earth and stones.

CAL-

CALCAREOUS GENUS.

He admits twelve Species.

Species I. Calcareous earth, uncombined with any acid; native lime of volcanos. Falconer on the Bath Waters, vol. i. p. 156. and 257. Monnet, Mineralog. p. 515.

Species II. Calcareous earth combined with the aerial acid. The varieties arranged in two series are transparent calcareous spar, opake spar, stalactites, tophi, incrustations, petrifications, agaric mineral or guhr, chalk, lime-stone, and marbles. Bayen, Journal de Phys. t. xi. p. 496.

Species III. Calcareous earth, combined with the vitriolic acid; gypsum, selenite or plaster.* He admits

* We observe here, that M. Kirwan reckons many earthy salts among the stones; though the solubility of most of them, and of this in particular, is nearly double that of the most soluble of stones.

It would be superfluous in this place to mention the proportions and the component parts of these pretended stones, as we shall speak of them in the history of salts. For this reason we shall mention these proportions only in the two last genera of Mr. Kirwan, which we consider as true earths. Note of the author.

two

two series, the transparent and the opake.

Species IV. Calcareous earth combined with the sparry acid. Fluor-spar, petunse of Margraaf. Series 1. Transparent fluors. Series 2. Opake fluors.

Species V. Calcareous earth combined with the tungsten acid. Tungsten or heavy stone. Woulfe in Phil. Transf. for 1779, p. 26. Scheele's Effays, also De Luyart's on Wolfram.

Species VI. Aerated calcareous earth mixed with a notable proportion of magnesia. Var. 1. Compound spar, described by M. Woulfe. Phil. Transf. for 1779, p. 29. Variety 2. Creutzenwald stone, analyzed by M. Bayen. 13 Rozier, p. 59.

Species VII. Aerated calcareous earth mixed with a notable proportion of clay. Variety 1. Calcareous marl. Var. 2. Travertino, margodes. Ferber's Italy, p. 117. 159.

Species VIII. Aerated calcareous earth mixed with a notable proportion of ponderous earth. Barytical limestone or marl from Derbyshire.

Species IX. Aerated calcareous earth mixed with a notable proportion of filiceous

siliceous earth. Var. 1. Stellated spar. Var. 2. Calcareous grit, Moellon, Pierre de Liais. Monnet Mineralogie, p. 216.

Species X. Aerated calcareous earth mixed with a small proportion of petrol. Swine stone.

Species XI. Aerated calcareous earth mixed with a notable proportion of pyrites; pyritaceous lime-stone, pierre de St. Ambroix, analyzed by Baron Servieres, 21 Rozier, 394. 22 Roz. 207.

Species XII. Calcareous earth mixed with a notable proportion of iron. Variety 1. Aerated calcareous earth mixed with iron. Rinman, Mem. Stockholm, 1754. Var. 2. Tungsten with iron. Cronstedt, M. Stockholm, 1751.

To these twelve species of the calcareous genus, Mr. Kirwan adds six other species of compound stones, in which the calcareous genus predominates. 1. The different simple calcareous species mixed together; as selenite and chalk, vitreous spar and tungsten. 2. Compounds of calcareous and barytical species; such as the yellowish stones from Derbyshire, consisting of lumps of chalk interspersed with nodules of ponderous spar. 3. Compounds of calcareous and muriatic species; such as the white marble mixed with

with steatites, the pietra telchina, the verde antico. 4. Compounds of calcareous and argillaceous species, of chalk and shistus; such as the green campan from the Pyrenees, the red campan, the yellow figured marble from Florence, the griotte, the amandola, the cipolin from Rome. (See Bayen's Journal de Rozin, vol. xi. p. 499. 801; and vol. xii. p. 51. 56, 57.) of chalk and mica; such as the cipolin from Autun, the macigno, pietra bigia, columbina or turchina of the Italians. 5. Compounds of calcareous and filiceous species, scintillating marble, volcanic pudding stone. 6. Lastly, Compounds of calcareous earth, with species of two or more genera, as the calcareous porphyry and lime-stone interspersed with schorl and mica.

BARYTIC GENUS.

He admits six Species.

Species I. Ponderous earth combined with the aerial acid. From Alston Moor in Cumberland, examined by Dr. Withering.

Species II. Barytes combined with the vitriolic acid. Ponderous spar.

Species III. Barytes combined with the sparry acid. It does not exist in nature, but is produced by art.

Species IV. Barytes combined with the tungstenic

tungstenic acid. This an artificial product like the foregoing.

Species V. Aerated barytes mixed with a notable proportion of flint and iron.

Species VI. Ponderous spar, mixed with a notable proportion of flint mineral oil, and terrene salts. Liver stone, white, grey, yellow, brown, or black.

MURIATIC OR MAGNESIAN GENUS.

Mr. Kirwan reckons eight species, among which he ranges all earths or stones, in which magnesia predominates, and such as exhibit the characters of the magnesian genus, though they may contain more flint than magnesia.

Species I. Magnesia combined with the aerial acid, and mixed with other earths. Var. 1. Mixed with flint; spuma maris. It is this substance the large Turkey tobacco pipes are formed of; terre à chalumeau of Canada. Var. 2. Mixed with calcareous earth and iron. Olive-coloured or blue earth found near Thionville. Var. 3. Mixed with clay, talc, and iron; greenish yellow from Silesia.

Species II. Combined with the aerial acid;

acid; above four times its weight of filex, and a small proportion of argill. Var. 1. Steatites. Var. 2. Lapis ollaris.

Species III. Aerated magnesia combined with filex, calcareous earth, and a small proportion of clay and of iron. Var. 1. Fibrous asbestos. Var. 2. Coriaceous asbestos, mountain cork.

Species IV. Aerated magnesia combined with filex, aerated calcareous earth, barytes, clay, and iron. Amianthus.

Species V. Pure magnesia combined with something more than its own weight of filex, about one third clay, near one third water, and about one or two tenths of its weight of iron. Serpentine, lapis nephriticus, gabbro of the Italians.

Species VI. Pure magnesia, intimately mixed with nearly twice its weight of filex, and less than its weight of clay. Venetian talc, Muscovy talc.

Species VII. Magnesia combined with the sparry acid. It has not been yet found in nature.

Species VIII. Magnesia combined with the tungsten acid. It is not met with in nature.

M. Kirwan adds to these, five other compound species, in which magnesia predominates. 1. The compounds of several muriated species among each other: steatites and talc, Briançon chalk; serpentine with steatites or asbestos. 2. Of the muriatic and calcareous species; red, green, yellow, or black serpentine; with veins, or spots of white calcareous spar, potzevera; the black is the Nero di prato, and the green the verde di suza of the Italians. 3. Of the muriatic and barytic species mixed together; serpentine with veins or spots of ponderous spar. 4. Of the muriatic and argillaceous species; steatites mixed with clay, mica, or schistus. 5. Of the muriatic and filiceous species; serpentine with veins of quartz, feldt-spar, or schorl.

ARGILLACEOUS GENUS.

Mr. Kirwan distinguishes fourteen species in this genus.

Species I. Clay saturated with aerial acid. Lac lunæ, according to the analysis of M. Schreber.

Species II. Clay combined with the aerial acid, and mixed with flex and water; clay, pipe clay, porcelain clay.

Species III. Clay saturated with the vitriolic

Species III. Olic acid; embryo alum in scales resembling mica. *Beaumé*.

Species IV. Clay saturated with the marine acid; embryo marine alum.

Species V. Clay combined with about one part and a half of filex, nearly one part of magnesia, and half a part of dephlogisticated iron; mica.

Species VI. VII. VIII. IX. Clay combined with siliceous, magnesian, and calcareous earths, with iron and bitumen; slate, blue shistus, pyritous shistus, bituminous shistus, argillaceous shistus.

Species X. Clay intimately mixed with near twice its weight of filex, almost its weight of magnesia, a small proportion of calcareous earth, and almost its weight of semi-phlogisticated calx of iron. Horn-stone, or horn-blende.

Species XI. Clay combined with four times its weight of filex, half its weight of pure calcareous earth, and something more than its weight of iron. Toadstone.

Species XII. Clay united to from upwards of two to eight times its weight of filex, about half its weight of lime, and from one to two times its weight of water; zeolite.

Species XIII. Clay imperfectly united to four times its weight of siliceous earth, and one third lava; pitch stone, lava.

Species XIV. Clay mixed with a notable proportion of red calx of iron, and sometimes steatites; red chalk.

To these Mr. Kirwan adds six compound species, in which the argillaceous genus predominates.

SILICEOUS GENUS.

He admits twenty-six Species of this Genus.

Species I. Siliceous earth nearly pure; quartz, crystal, sand.

Species II. Siliceous earth, with $\frac{1}{4}$ of clay, and $\frac{1}{10}$ of calcareous earth; common flint.

Species III. Siliceous earth, with $\frac{1}{3}$ of clay, and $\frac{1}{15}$ or $\frac{1}{17}$ of calcareous earth; petrosilex, chert.

Species IV. Siliceous earth, with $\frac{1}{3}$ of argill, and $\frac{1}{8}$ or $\frac{1}{7}$ of calx of iron. Jasper.

Species V. The finer flints mixed with various proportions of other earths and iron. Precious stones of the second order. Agate, opal, chalcidony, onyx, cornelian, sardonix.

Species VI. Siliceous earth, with from
an

an equal, to three times its weight of argill, and from $\frac{1}{4}$ to an equal weight of calcareous earth, together with from $\frac{1}{4}$ to an equal part of iron. Precious stones of the first order, Ruby, topaz, hyacinth, emerald, sapphire.

Species VII. Amethyst. Its composition is not known.

Species VIII. Siliceous earth united to $\frac{1}{4}$ of its weight of calcareous earth, less of magnesia, with an exceeding small proportion of iron, copper, and sparry acid. Cryopræse.

Species IX. Siliceous earth, with blue martial fluor, and a small proportion of gypsum. Lapis lazuli. M. Margraaf found it to contain clay, gypsum, filex, and iron. M. Rinman found it to contain the sparry acid.

Species X. Jade. Mr. Kirwan suspects it to consist of filex, magnesia, and iron.

Species XI. Siliceous earth with clay, ponderous earth, and magnesia. Feldt-spar, petuntze, Labrador stone. 100 Parts of the white feldt-spar contain about 67 of siliceous earth, 14 of argillaceous, 11 of ponderous earth, and 8 of magnesia.

Species XII. Siliceous zeolite. It is found at Maffiberg. It differs from the common zeolite in giving fire with steel, which shews that it contains filix.

Species XIII. Siliceous earth, with more than one third of its weight of clay, and $\frac{1}{9}$ of calcareous earth, without iron. White garnet of Vesuvius. 100 Parts contain, according to Bergman, 55 of siliceous earth, 39 of clay, and 6 of calcareous earth.

Species XIV. Siliceous earth with clay, calcareous earth and iron. Garnet. According to Mr. Achard, 100 parts of this stone are composed of 48 siliceous earth, 30 clay, 12 calcareous earth, and 10 iron.

Species XV. Siliceous earth with much clay, about tenth of calcareous earth, and small portions of iron and magnesia; shoerl.

Species XVI. Bar shoerl, stangen shoerl of the Germans, found by M. Fichtel in the Carpathian mountains, embodied in lime-stone, and crystallized in prisms. It slightly effervesces with acids. According to M. Bindheim, 100 parts of it contain 62 of filix, 21 of calcareous earth, 6 of clay, 5 of magnesia,

nesia, 2 of iron, and 3 of water.

Species XVII. Tourmalin. The proportion of the principles of the tourmalins of Tyrol, Ceylon, and Brazil, is thus exhibited by Bergman.

		Clay.	Silex.	Calc.	Iron.
In one hundred parts of the	Tourmalin of Tyrol	42	40	12	6
	— Ceylon	39	37	15	9
	— Brazil	50	34	11	5

Species XVIII. Basaltes, trapp. 100

Parts contain, according to Bergman, 52 of filiceous earth, 15 of clay, 8 of calcareous, 2 of magnesia, and 25 of iron.

Species XIX. Rowly rag. A dark grey stone of a granulated structure; which becomes magnetic by heat, and melts by a strong fire. By exposure to air, it acquires an ochreous crust. 100 Parts, according to Withering, contain 47. 5. of filiceous earth, 32. 5. of clay, and 20 of iron.

Species XX. Silex, clay, iron, and in most specimens calcareous earth, melted by volcanic fires.

1. Cellular lavas, erroneously called pumice stones by some. They have undergone the lowest degree of fusion. These stones contain from 45 to 50 per cent. of silex; from 15 to 20 per cent. of iron, 4 or 5 per cent. of pure calcareous earth, and the remainder clay.

2. Compact lavas. These have undergone the second degree of fusion. They have few cavities, and give a clear sound when struck.

3. Vitreous lavas. Completely melted, and forming vitrifications of different colours, generally black or ash-coloured, rarely blue or greenish. M. Saussure has imitated all these species of lavas, by melting more or less perfectly the compound argillaceous species into which horn-stone enters, as the most copious, which he therefore calls horn-rock (*Voyage dans les Alpes*, p. 127.)

Species XXI. Siliceous earth mixed with above one tenth of its weight of magnesia, and a small portion of calcareous earth. Pumice stone.

Species XXII. Siliceous earth mixed with less than its own weight of magnesia and iron. Martial muriatic spar. Pisolites found at Saint Marie aux Mines, by M. Maret.

Species XXIII. Siliceous earth, with $\frac{2}{3}$ of its weight of mild calcareous earth. Turkey stone. It hardens with oil.

Species XXIV. Siliceous earth mixed with mild calcareous earth and iron. Rag-stone.

Species XXV. Arenaceous quartz consolidated by a smaller proportion of calcareous or argillaceous earth, and a still smaller of iron. Grit, which

which may be reduced to sand by pounding. Sand-stone. Free-stone.

Var. 1. Grit with a calcareous cement, from Fontainebleau. It effervesces with acids. Var. 2.

With an argillaceous cement. It does not effervesce, and is used for building, and likewise to sharpen tools, to filter water, &c.

Species XXVI. Siliceous sand, consolidated by semi-phlogisticated calx of iron. This stone does not, like the foregoing, fall into sand when powdered; it gives fire with steel, and does not effervesce with acids, unless it contains testaceous particles. Its colour is usually brown or blackish, but it grows reddish or yellowish, and moulders by exposure to air. Mess. Edward King, and Gadd, have shewn that semi-phlogisticated iron has the property of agglutinating earths, while the same metal, completely dephlogisticated, does not possess that power.

To these Mr. Kirwan adds six other compound species, in which the siliceous earth predominates. The varieties referred to these species are compounds frequently found in mountains of ancient formation; and it is chiefly from the observations made by Mr. De Saussure

Sauffleure, in the Alps, that the English chemist establishes the order of this supplement. Among these varieties, we find the different granits, pudding stones, granitello, grani-tier, porphyry, gneis, variolite, &c.

C H A P. IV.

Concerning the Chemical Analysis of Earths and Stones.

NOtwithstanding the great attention which for some years past has been paid to the analysis of earths and stones, it must be confessed that we are still very far from possessing a sufficient number of well established facts to serve as the basis of a methodical division of those substances. It is for this reason, that the chemical methods hitherto offered to the public are so different from each other, and this circumstance rendered it necessary to exhibit, in the present work, the systems of three celebrated chemists, though the interval between the publication of their respective works is by no means considerable.

The principal advantage derived from the labours of our cotemporaries in their inquiries into the nature of earths and stones, consists

consists in the discovery of methods for obtaining a knowledge of their principles. The methods of analyzing these substances is rather complicated, for which reason I shall in the present chapter exhibit merely its outlines. In fact, if we except the action of fire, air, and water, which may, without difficulty, be estimated by beginners, who have read the former part of this work, there is no part of the general process which can be properly spoken of in this place without a degree of irregularity, by no means to be admitted in a book of science: for the advantageous use of saline matters cannot be explained till the properties of those bodies have been previously attended to. I shall refer the detail of the methods of decomposing earthy substances by means of acids and alkalis to another part of this treatise.

When it is proposed to examine into the chemical nature of any earth or stone, it is necessary, first, carefully to observe its physical properties, such as its figure, colour, weight, &c. The extraneous matters, which are always more or less abundant, must then be separated by washing, or otherwise, in order that the substance may be had pure and unmixed. A stone must be reduced into powder before its analysis can be proceeded upon. The action of fire is one of the first tests to which earths are commonly exposed.

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A few ounces of the substance under examination, being put into a crucible of well baked clay, or porcelain, is heated in a good furnace, such as that of Macquer, or still better in the potter's or glass-maker's furnace. It must be remarked, that the argillaceous earth, which constitutes the case or principal part of the crucibles employed in this operation, very often contributes greatly to the change produced by heat in the included substance. There is not, however, any method of obviating this inconvenience, which in fact is of no great consequence in the comparative analysis of a considerable number of stones. For some years past chemists have availed themselves of the blow-pipe in the examination of mineral substances by fire, and it is certainly of advantage to employ this method as well as the other. The mineral substances are exposed to the flame of a lamp or candle, urged by the blow-pipe, either alone or mixed together, or with the addition of certain salts hereafter to be described.* The apparatus described in my *Memoires de Chimie*, which is calculated to throw a stream of vital air, on ignited charcoal, and whose effects are so considerable, as to equal those of the most

* See the Essay on the Blow-pipe, by Bergman, annexed to Mongez' *Manuel du Mineralogiste*, or Cullen's English Translation of Bergman.

powerful

powerful burning glasses, may be advantageously used in this inquiry. These small experiments exhibit a greater or less degree of fusion, or some other changes of form, colour, consistence, &c. which are to be very accurately described. This trial by fire must be repeated in earthen retorts, with receivers, and likewise the pneumatological * apparatus, in order to collect the water, and aeriform fluids, which are disengaged. The last mentioned products are not afforded, but by such saline earthy substances as are considered by naturalists as stones; but as these are often mixed with true earths, it is proper to mention in this place the general method of examining them. The action of fire on stones, shews whether they are vitrifiable, argillaceous, or mixed; but as most stones are of the last mentioned kind, and may contain several different substances to the numbers of five or six, and those in various proportions, it becomes necessary, in almost every instance, to make use of other methods to determine their composition: these processes consist in the application of a variety of acid and alkaline solvents, whose successive action separates the constituent principles.

* For a description of this apparatus, consult the article gas in the Dictionnaire de Chimie, in the treatise on the different kinds of air, by Sigaud de la Fond, &c. &c. T.

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The action of air and of the vapour of water, on earthy substances, may likewise serve to enlarge our knowledge of their nature and principles. Some earths are not altered by these agents, others are divided, and by degrees changed in their form, colour, and consistence: these phenomena take place more especially in very compounded stones, and such as contain much iron. The lixiviation or washing in hot or cold water serves, besides, to shew the presence of saline matters, often contained in them.

It is by these different methods, that modern chemists have succeeded in determining the nature and proportion of the principles, which enter into a considerable number of earths and stones. A more ample account of this subject will be given in our next section on saline substances.

P A R T II.

S E C T I O N II.

SALINE SUBSTANCES.

C H A P. I.

Concerning Saline Substances in general, their Characters, Nature, and the Method of classing them.

THE number of saline substances is very considerable, and they possess peculiar characters, by which they are distinguished from the substances before treated of in this work. These characters are founded on certain properties, which it must be confessed are not accurately distinctive of their true nature: by this means the class of salts has been extended too much, the general properties being common to a great number of bodies.

Taste and solubility in water, which have always been given as the characters of saline substances, are properties of many bodies which are not saline; as for example, all mucilages, whether of the vegetable or animal kingdoms: and on the contrary, these two properties are scarcely perceptible in several saline substances. Naturalists have not succeeded

succeeded better in their definition of salts. The crystalline form and transparency which several authors have assumed as characteristic of this class, belong likewise to many other matters, more especially earths, and are besides wanting in some of the salts. It was therefore with great reason that Macquer asserted, that the limit between saline matters, and such as are not saline, is unknown.

However, as it is necessary to come to some decision respecting these properties, we shall give a general account of them before we proceed to the particular history of each salt.

We admit as saline substances, all such as possess several of the four following properties. 1. A strong tendency to combination. 2. A greater or less degree of sapidity. 3. A greater or less degree of solubility in water. 4. Perfect in combustibility. Before we examine each of these properties singly, it must be observed, that the saline quality of any given body is greater, the more of these properties it possesses, and the greater their intensity. It must not, however, be concluded, that substances are not of a saline nature, because these properties are scarcely evident in them; as it may often happen, that two species, which possess them in a very small degree, exhibit them still less when they come to be united; and there are likewise instances of the contrary effect taking place; but
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in these cases, a more varied application of the chemical analysis, or synthesis, may serve to exhibit the saline properties more evidently.

§ 1. Concerning the tendency to combination, considered as a character of saline substances.

The greater number of salts have a tendency to combine with many different substances. It is among the salts, that the most active bodies, with respect to combination, are found; for this reason the chemists have at all times made great use of them, and have dignified certain salts with the names of solvents and menstrua. This tendency to combination differs greatly in the several species of salts: some possess it in so intense a degree, that they corrode, dissolve, or destroy every thing they touch, and that even the vitrifiable and quartzose stones cannot withstand their action; such are several of the pure salts called acids and alkalis: others, though they do not so strongly tend to combination, nevertheless unite with great readiness to several substances: and lastly, there are salts which do not possess this property in any sensible degree; as is often observable in compound salts, whose principles have a strong affinity with each other, and are mutually saturated. It is not to be wondered that salts are seldom found in nature in a state of purity, when we attend

to the effects of this property, of combining with various substances.

§ 2. Of Taste considered as a Character of Saline Substances.

Sapidity has hitherto been considered as being so far peculiar to saline substances, that many philosophers have concluded these bodies to possess it exclusively, and that they are the principle of sapidity in all other bodies: though this opinion is not yet clearly proved, because there are many bodies not at all saline, as for example, the metals, which have a very sensible taste. But though instances may be urged, of certain saline matters which have scarcely any taste, yet it cannot be denied, that the most eminently sapid bodies belong to this class, for which reason we have assumed this property as one of the leading characters of salts. The sapidity of saline matters varies like their other properties in the different species. In order to determine its origin, and more especially the cause of the differences of its energy, it will be necessary to shew in what it consists. By sapidity, we commonly understand an impression made on the organs of taste, by which we determine the good or bad qualities of any substance with regard to salubrity; it is therefore a peculiar action of the sapid body on the

the nerves of the tongue and palate of animals. But it may be asked, whether this property of bodies enables them to act sensibly only on the nerves of the tongue, and whether it may not be equally exerted on all those parts of an animal which contain nerves. They who are acquainted with the animal œconomy, cannot deny that the action, which excites the sensation of taste, must produce its effect on any nerves where-soever situated, and that it must be proportioned to the sensibility of the subject, and the organs to which it is applied.

In this way of considering sapidity, we are naturally led to conclude, 1. That its impression will be scarcely sensible on such parts of bodies as contain few nerves, or whose nerves do not possess a considerable degree of sensibility, on account of their being covered : as on the skin, where they are defended by the reticular membrane and epidermis. It follows therefore, that the taste of any salt must be very strong and active, before it can act sensibly upon the skin. 2. That the impression will be made with much more efficacy on these organs, whose nerves are large, numerous, and of a form proper to admit an extended contact, or more violent agitation, and whose epidermis is very thin, so as to leave the nerves almost uncovered. The superior part of the tongue, the palate, and the whole in-

ternal surface of the mouth, are capable of perceiving the taste of a great number of bodies, which make no impression on the less sensible organs of the skin. 3. That bodies which have no taste when applied to the skin, or put into the mouth, may nevertheless produce a considerable effect on parts more delicately organized, or whose nerves possess a greater degree of sensibility; as is the case of the stomach and intestines.

These considerations being admitted, we may distinguish three classes of tastes, and of sapid bodies, to which all saline matters may be referred. The first class comprehends salts of the strongest taste, capable of acting on the skin; the impression of this taste is so strong, as to cause very acute pain, and if its action be continued for a certain time, the organization of the skin is entirely destroyed. This taste is causticity, and the salts which possess it are called caustic. The second class comprehends those whose sapidity is of a mean degree of intensity, and is not to be perceived but by the organs of taste; these are commonly distinguished by different names, as bitter, astringent, acid, acrid, urinous, &c. In the third class, we shall arrange saline substances, whose taste is sensible only in the stomach and intestines: these are not numerous. It must be observed, that there are many degrees in each of these classes, by which bodies differ from
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from each other in intensity of taste. Thus among caustic salts, some act much more strongly than others; the former immediately destroying the organization of bodies, while the latter require a more considerable space of time to produce the same effect. This observation applies likewise to the bitter, astringent and urinous salts, as well as to those which have no sensible action but on the nerves of the stomach. Hence we are naturally led to the conclusion, that the several tastes are degrees of the same property, from the most caustic, to that whose action is too feeble to be perceived, but on the highly sensible organs of the stomach; and this reflection seems to shew, that all tastes owe their origin to one and the same cause.

To determine the cause of sapidity, it will be proper to consider its strongest degree, that we may better distinguish the phenomena, and deduce its mode of action; the inquiry therefore relates to the cause of causticity; a property which has always been a subject of conjecture among chemists. Lemery observing that very hot bodies are excessively caustic; and likewise, that such salts, as possess this property, have been subjected to a strong degree of heat in their preparation, attributed the property of causticity to the particles of fire, which he supposed to be deposited among the particles of bodies. Mr. Baumé espoused this opinion.

Meyer, an apothecary of Osnaburgh, after making a series of inquiries into the nature of caustic salts, constructed an ingenious system, or hypothesis, to which many chemists have been much attached, though at present it is held in no esteem. This philosopher attributed causticity to a principle which he considered as a compound of fire, and a peculiar acid; this he denominated causticum, or acidum pingue, after the ancient chemists. He pursued this principle through its transitions and combinations, as Stahl had done before with his phlogiston; but his system was defective in the same manner as that of Stahl, as he did not succeed better in proving the existence of his causticum, than Stahl did that of his phlogiston. Dr. Black, whose researches were directed to the same subjects as those of Meyer, gave the finishing stroke to his doctrine, by clearly shewing, that the causticity of lime and alkalis, far from being owing to the addition of any principle, as Meyer thought, arises, on the contrary, from the subtraction of an elastic fluid, which we shall hereafter describe under the name of the cretaceous acid.

Macquer is beyond controversy the chemist, whose inquiries into the cause of causticity have been attended with the greatest success. The doctrine explained by him on this subject, in his Chemical Dictionary, is

so clear, and established on such conclusive facts, that it is impossible to forbear assenting to his opinion. After observing that caustic bodies corrode and destroy our organs, by combining with their constituent principles, he remarks, that in proportion as this combination proceeds, the caustic body by degrees loses its force, and that it ceases to be such, as soon as it has dissolved as much of the animal matter as it is capable of uniting with. Thus it is that the pure fixed alkali, or lapis causticus, corrodes the skin on which it is applied, and after a certain time becomes saturated, and ceases to act. Causticity therefore depends on the tendency to combination, and the effect of this force on our organs, is merely the result of a combination of the caustic matter with the matter of which the organs are formed; in the same manner as caustic bodies lose their efficacy, when combined with any other substance with which they have a tendency to unite. The most tasteless salt owes its want of causticity, to its being already saturated with some other substance, and its taste will be rendered stronger, by the separation of that substance, as the whole series of chemical facts evinces.

§ 3. Concerning Solubility, considered as a Character of Saline Bodies.

Solubility in water has been assumed by all chemists, as one of the leading properties of salts. Yet this property, like that of taste, or the tendency to combination, is subject to great varieties. In some salts it is so powerful, that they cannot be deprived of the last portions of water they contain, but by elaborate processes long continued. Others have only a mean degree of solubility, which may be ascertained with considerable accuracy, as is the case with the neutral salts. And lastly, there are certain saline matters, which are so little soluble, that they even seem in this respect to belong to the class of earths, and have in fact been considered as such by naturalists. The limits between those two classes of mineral bodies are very difficult to be determined, and chemists are not agreed on this head. Mr. Kirwan, in his mineralogy, appears to have adopted the opinion of Bergman, who thinks that all substances, which require more than one thousand parts of water for their solution, ought to be ranked among earths; and that all, which are more soluble, ought to be esteemed as salts. If this proposition should be received among chemists, as I think it deserves to be, we shall avoid the

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the diversity of opinions and of language, which has hitherto prevailed, to the discouragement and hindrance of such as enter into the study of this science.

There is the same correspondence between the taste and solubility of salts, as there is between this last property, and the tendency to combination. For the solubility in water is an immediate consequence of the tendency to combination, and must therefore follow the same laws. It is found, that the more taste and activity any salt possesses, the more soluble it is in water, and this general fact depends on their respective nature and properties.

§ 4. Of Incombustibility, considered as a Character of Saline Bodies.

It is more difficult to acquire a clear idea of this property of saline bodies, than the others we have been speaking of. They have not yet been considered by any chemist in this point of view; and many writers have asserted, that some salts, and among them nitre, are truly combustible.

To shew the fallacy of this opinion, and to prove that all mineral salts are perfectly incombustible, would require a more intimate knowledge of the properties of these substances, than the reader can yet be supposed to possess. Yet as we are of opinion,
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that this character of salts is one of the most evident, and the most necessary to be known, it will be proper in this place to exhibit a short account of the doctrine we hold respecting it, which will be explained, and incontrovertibly established in the accounts we shall hereafter give of the respective saline substances. The valuable experiments of Mr. Lavoisier shew, that many combustible matters afford a residue after combustion, consisting of an acid of a peculiar nature. Combustion, as we have already explained, is nothing more than a combination of the base of vital air with combustible bodies. All bodies which have been burned, or are combined with the base of air, enter into the class of incombustible bodies; or which is the same thing, their tendency to combine with this base being satisfied, they are no longer capable of passing through the process a second time. These principles being once admitted, if it be found that many salts are the residues of various combustible matters which have been burned; and moreover, if all salts are found to contain the base of pure air, and possess the characters of substances which have passed through the process of combination, it will easily be conceived that they cannot be combustible. These assertions are founded on a great number of facts, as will hereafter be seen; and they

they evince that salts are very compounded substances, most of them being formed by the union of certain combustible bodies with the base of pure air. And it will likewise be understood with equal facility, that this character of incombustibility may be considered as the most certain and invariable property of saline matters. The complete proof of the important assertions here thrown out, will, we hope, appear in the most satisfactory manner in those parts of our work, wherein we can with propriety enter more largely into this subject.

It must be confessed, that there are several salts, to which we cannot apply our reasoning in so conclusive a manner; but of these we may make the same inferences by analogy, as the force of facts compels us to do respecting the others: and this analogy gives us reason to expect, that it will not be long before every part of this theory will be firmly established upon experimental proof.

§ 5. Concerning the Nature and Composition of Saline Substances in general.

Stahl, who paid great attention to the nature of saline bodies, was of opinion that they are formed of water and earth. He collected every fact which was known in his time, and applied them to the illustration of his

his sublime theory. But that period of improvement has been succeeded by another, in which, by the multiplicity of experiments, and the magnitude of the discoveries, concerning the influence of air in chemical phenomena, the theory of salts as invented by Stahl, and explained with great perspicuity by Macquer, is no longer found adequate to the explanation of the nature and composition of those bodies.

Though the chemical nature of salts is not yet perfectly understood, and the general facts will not permit us to assert, that one single principle is the cause and origin of all saline bodies, as many eminent philosophers have thought; yet it must be admitted, that we are better acquainted with their composition than formerly. It is known that they, for the most part, contain a very great quantity of vital air, and that this fluid is fixed in combination with combustible matter, of a different nature in the different kinds of salts. There are sufficient proofs that many acids are thus composed; and it may be strongly presumed by analogy, that alkalis are compounded nearly in the same manner. As to the matter of fire admitted to exist in salts by many chemists, there is too much uncertainty respecting its nature, and even its existence, to justify the adoption of any decided opinion. Lastly, the presence of earth in salts, is not shewn
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by any direct experiment. It is true that all salts, as found in nature, are vitiated by the addition of earthy matter; but this is merely accidental, and by no means a necessary or essential component part. All that is at present known concerning the general principles of saline bodies therefore is, that they contain vital air united to combustible bodies; that salts are mostly the residues of bodies which have suffered combustion; and that the proportion of these two bodies, and of course the properties thence resulting, are susceptible of great variation. Every doctrine laid down in treatises of chemistry, respecting the composition of salts in general, must amount to nothing more than is here given; or if it proceed further, it must be entirely hypothetical, and most probably false.

§ 6. Concerning the Distribution, or Methodical Division of Mineral Salts.

Those salts, which belong to the mineral kingdom, are very numerous; many of them are the products of nature, and are formed by the action of fire, water, and air, and by the destruction of organized bodies; the greater number however are formed by art, or at least have not yet been found among natural products. The methodical treatment of these substances, requires that they should

should be divided into orders, genera, and species, as has been already done with earths and stones; we shall class all mineral saline matters into two orders.

The first contains such saline substances as are reckoned simple; we have called them primitive salts, because they serve to compose the salts of the second order. The following order contains secondary, compound, or neutral salts, which are formed by the mutual combination of the simple salts.

Each of these orders is divided into genera and species; the mineral kingdom, as far as our present knowledge extends, contains nine genera, and fifty-four species of salts, either simple or compound; this number will be much more considerable, when certain substances, lately examined, shall be better known, as we shall observe at the end of this section.

C H A P. II.

Concerning the three Salino-terrestrial Substances.

Order I. Simple or Primitive Salts.

WE distinguish those salts by the name of simple or primitive, which were formerly thought to be so by all chemists; but as accurate experiments have proved that they are for the most part compounded, we must here take notice, that they cannot with propriety be called simple, except when compared with the salts of the second order: the epithet primitive is more accurate, because these compose, when united, the salts which we call secondary. We divide this order into three genera, comprehending saline terrestrial substances, alkalis, and acids. The present chapter contains an account of the former, and is followed in the succeeding chapters by the history of acids and alkalis.

Genus I. Salino-terrestrial Substances.

The three substances which compose this genus have hitherto been considered
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as earths, whose characters manifestly resemble those of salts.

The obvious saline properties they exhibit, together with the properties of earths, in a less evident degree than either the siliceous or argillaceous earths, has induced us to place them before the salts, that they may serve as a connecting link between the latter and earths, from which they likewise differ, in their much stronger tendency to combination.

It must be observed, that the salino-terrestrial matters, as well as the primitive salts, concerning which we are about to speak, are supposed to be perfectly pure, though they are never met with in that state without previous artificial processes. Of these processes, however, we cannot yet speak consistently with regularity; the history of neutral salts will shew the chemical methods of decomposing them, as well as the simple or primitive salts.

This first genus contains three species.

Species I. Ponderous Earth.

Ponderous earth received its name from Messrs. Gahn and Scheele, Swedish chemists, who first discovered its combination with the vitriolic acid, with which it forms a very ponderous salt. M. de Morveau calls it *barote*, which Bergman has translated into Latin

Latin, by the term barytes; its specific gravity exceeds 4000, according to Kirwan. This earth is never found in a state of purity: Messrs. Margraaf and Monnet imagined it to be of the nature of absorbent or calcareous earth. The latter, however, observed that it possesses certain peculiar properties, and was inclined to consider it as a peculiar earth. It has not hitherto been much examined in its uncombined state. The compounds it forms with acids, and its affinities, afford the means of distinguishing it from every other substance.

Pure ponderous earth obtained by the methods hereafter to be described, is of a pulverulent form, extremely fine, and of a white colour. I have not observed that it impresses the sense of any peculiar taste on the tongue.

It is not yet known whether the action of light alters its colour.

The ordinary fire of our furnaces is insufficient to melt it; it communicates a blue or greenish colour to the crucible in which it is heated, and is itself lightly tinged with the same colour: a property that appears to depend on the mutual action exerted between this earth and clay. Mr. D'Arcet asserts, that a very violent heat melts it in a crucible either of clay or iron. Exposed to the air, its weight increases, and it combines, though very slowly, with the cretaceous acid of the atmosphere;

mosphere; the effect of vital air on this substance is not known.

It is soluble in water, though very sparingly, 900 parts of the fluid being required to suspend one part of ponderous earth. Water, thus saturated, gives a fable green colour to the tincture of violets.* This solution exposed to the air becomes covered with a thin pellicle, which if taken away, is from time to time renewed; the cretaceous acid contained in the atmosphere combining with the ponderous earth, and causing this phenomenon, which is similar to what happens with lime-water in like circumstances. The same solution, evaporated to dryness, leaves the ponderous earth, from whose weight the solubility of this substance may be estimated. The necessity of using distilled water in this, as well as in every chemical process where accuracy is required, is sufficiently obvious.

Ponderous earth has no sensible action either in the dry or humid way on filiceous or argillaceous earth.†

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*Tincture of violets is a solution of the colouring matter of these flowers in water; the fresh, or newly made tincture, is a much nicer test than the syrup of violets; but as the syrup may be employed in many cases to exhibit the presence of saline matter, we shall have frequent occasion to mention it instead of the tincture. F.

† It is proper to observe in this place, that for the sake of order, I do not speak of the combination of two bodies
till

This salino-terrestrial substance is found less abundantly in nature than either of the others of that description. Some modern chemists suppose it to be a metallic calx, as Bergman long since suspected from its weight, and that of the compounds into which it enters, as well as from the precipitate it forms, when the Prussian alkali is added to its acid solution. It is asserted that Mr. Gahn, a disciple of this celebrated chemist, has succeeded in obtaining this substance in the form of a regulus; but the fact requires confirmation. Its intimate nature is yet unknown; as no one has succeeded either in separating its principles, or imitating it by composition.

Ponderous earth, in a state of purity, has not been applied to any useful purpose; its solutions in acids are employed as re-agents, as will be more fully shewn hereafter.

Species II. Magnesia.

Magnesia is usually obtained from Epsom

till each has been first singly described. In conformity with this rule, I have not in the history of ponderous earth taken notice of the changes it suffers by combination with other bodies, except light, fire, air, water, vitrifiable and argillaceous earths; because these are the only substances yet treated of: its other combinations will therefore be treated of as we advance. This order possesses the double advantage of being very methodical, and of facilitating the progress of the learner. F.

salt, and abounds in the mother water of nitre, and in a great number of stones, &c. It is not found pure in nature, but almost always in combination with an acid. Black is the first chemist who made an accurate distinction between this substance and lime.

Magnesia obtained in a state of purity by the methods to be described in future, is in the form of a very fine powder, considerably resembling flour in its appearance and feel; its specific gravity is about 2,33, according to Kirwan; it has no sensible taste on the tongue, but appears to act on the stomach, for it is a slight purgative; it gives a faint greenish colour to the tincture of violets, and converts turnsole to a blue. The action of light on magnesia has not been accurately noticed, but it does not appear to be considerable. When exposed to a violent heat it does not melt, according to the experiments of M. D'Arcet. Macquer has observed likewise, that it remains unchanged in the focus of the burning lens of the garden De L'Infante. M. De Morveau observed the same result, after exposing magnesia for two hours to the most violent heat of Macquer's furnace. Mr. Butini, who has published a set of valuable inquiries into the nature of the magnesia of Epsom salt, has observed that this substance contracts in its dimensions by a strong heat, so that its particles become sufficiently hard to scratch iron.

iron. It is also affirmed that a small cube formed out of a paste of magnesia and water, exposed to the focus of Parker's lens, contracted suddenly in all its dimensions: this property should seem to point out some resemblance between magnesia and clay, with which it is often found naturally combined, as has been observed in the history of steatites, asbestos, serpentine, &c.

Magnesia heated in a retort loses nothing but the water it contained; but at the same time it acquires a considerable degree of phosphorescence, as Mr. Tingry, apothecary at Geneva, has observed. Exposed to the air, it remains long without alteration. M. Butini placed 10 grains of calcined magnesia in a porcelain saucer covered with a paper in a dry chamber, and after near two years it had gained no more in weight than about the eighth of a grain. It appears to combine very slowly with the cretaceous acid of the atmosphere. It is very sparingly soluble in water: 4 ounces and a quarter of pure water being left in a bottle for three months, together with one eighth of an ounce of calcined magnesia, first boiled together with the fluid, afforded M. Butini a residue by evaporation, which he estimated to be the one fourth of a grain.

Mr. Kirwan asserts, that it requires 7692 times its weight of water to dissolve it in the ordinary temperature of the atmosphere;

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that is to say, about 60 degrees of Fahrenheit's thermometer. Notwithstanding this difficulty of solution, magnesia forms a kind of paste with water. This paste is not ductile, but is easily broken, and the water is soon separated either by heat, or the contact of dry air: the solution of magnesia has no sensible taste, and scarcely alters the colour of syrup of violets.

The action of magnesia on the pure earths is not yet well known; it is decided, however, that it cannot be fused with either the siliceous or argillaceous earths singly, but it may with both together.

The mutual action between this and the ponderous earth has not been inquired into.

The intimate nature of magnesia is not more known than that of ponderous earth; there is no experiment which can be urged to prove that it is a modification of any other earthy or saline substance, as certain chemists have imagined. No one has yet succeeded in separating magnesia into its component parts; neither has it yet been formed by synthesis; in the present state of chemistry it must therefore be considered as a simple substance.

Pure magnesia, which Dr. Black calls caustic, is employed in medicine, as an absorbent and purgative. It is to be preferred to the ordinary magnesia in those cases wherein acidities abound, because the creta-
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ceous acid contained in the latter is disengaged by the acids in the first passages, and produces flatulences, with all their numerous attendant consequences: it preserves flesh for a long time, and even restores putrified bile. Mr. Bergman attributes to it the property of rendering camphor, opium, resins, and gum resins, soluble in water; though pure magnesia, as we have observed, is itself scarcely soluble in that fluid: these preparations of Bergman are unknown in France.

Species III. Quick Lime.

Quick lime is a white substance, whose parts cohere more strongly together than those of the two substances last treated of; it is usually in the form of a stone, of a dirty white; its taste is burning, acrid, and urinous; and is sufficiently strong to cause inflammation when applied to the skin; its specific gravity is about 2,3, and it is pulverulent and friable. It is found native in the vicinity of volcanos, as Mr. Monnet observed among the mountains of Auvergne.

Lime converts the syrup of violets to a much deeper green than is produced either by ponderous earth or magnesia; it even almost destroys this colour, and converts it into a dirty yellow.

Lime exposed to a very violent heat, as for example, that of a glass-house, suffers no alteration.

alteration. Parker's burning glass, however, appears to have produced a slight commencement of fusion, though the lime was placed on a support of charcoal : its extremities are sometimes melted when exposed to a strong heat in a crucible of clay ; but this effect is produced by the mutual action of the two earths on each other.

Lime exposed to the air swells, breaks, and is reduced to powder, its bulk being considerably increased: it is then called lime slaked in the air. This change takes place more quickly, accordingly as the air is more humid ; it is attended with heat, and the dilatation is sufficiently strong to burst casks in which lime is contained. If this substance be examined after being slaked, by exposure to air, it is found to consist of a very fine white powder, remarkably increased in weight, while the intensity of its taste is diminished. This change is principally owing to the water contained in the atmosphere, which has a strong tendency to unite with the lime: if slaked lime be heated in a retort, it returns to its original state. The action of water on quick lime is very strong. When a small quantity of this fluid is poured on lime it is quickly absorbed, the lime appearing as dry as before : after a short interval of time it bursts into pieces, producing a degree of heat sufficient to reduce the water into vapours, with a remarkable

markable hissing noise. These vapours appear in the form of a white smoke, and have a peculiar smell: the lime soon falls into a white powder; the heat, the agitation, and the vapours gradually disappearing. If this extinction be made during the night, or in a dark place, many luminous points are observed on the surface of the lime. All these phenomena are consequences of the activity with which this salino-terrestrial substance unites with water; but in order that they may take place, it is required that no more water be used than the lime can very quickly absorb, so as to become immediately dry. It seems that the disengagement of heat from these two bodies changes their state, and that flaked lime in its pulverulent form, contains water in a dry and solid state. This dry state of water, which takes place in many combinations, attended with heat, and which produces solid compounds, whose specific heat is less considerable than before, has not been enough attended to by chemists, or to speak more properly, has been totally unobserved till lately. When lime, in this experiment, has absorbed as much water as it can combine with and remain dry, it is called dry flaked lime; it then no longer produces heat by the addition of water, but is dissolved without any sensible motion, if the quantity of water be considerable. The white opaque fluid, or mixture,

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is called milk of lime; if the quantity of water be still greater, the lime is perfectly dissolved, and the liquor becomes transparent. Mr. Kirwan affirms, that 680 parts of water are required to dissolve one of lime, at the temperature of 60 degrees.

This solution, which is known by the name of lime-water, is clear and limpid; its specific gravity scarcely exceeds that of common water; its taste is acrid and urinous; and it readily converts syrop of violets to a green. By evaporation in closed vessels, very pure water is obtained, the quick lime remaining behind; but a red heat is necessary to separate the last portions of water, which are retained with great force: after this treatment, the lime becomes heated by the addition of small quantities of water as before.

Lime-water exposed to the air becomes covered by a dry pellicle, which gradually increases in thickness and solidity: if this pellicle be taken away, a second is formed, and after that a third, and so forth, till the whole of the water is evaporated. These pellicles have been improperly called cream of lime; it was formerly thought to be a peculiar salt formed by the union of the most subtle part of the calcareous earth united to water; and much has been written concerning this pretended salt of lime. But it is

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now admitted, since the experiments of the celebrated Black, that the saline properties of cream of lime are less intense than those of the lime itself; and that it is a peculiar neutral salt composed of lime, and an acid extracted out of the atmosphere. We shall speak of this salt under the name of chalk.

Lime combines with vitrifiable earth in the humid, as well as in the dry way. When sand is mixed with lime newly flaked, or with quick lime sprinkled with a small quantity of water at the time of mixing, these two bodies become consistent, and form what is called mortar. The state and quantity of the lime, as it is more or less perfectly calcined; its previous flaking, with a greater or less quantity of water, or the flaking of it at the time of mixture; the nature of the sand with regard to its magnitude, its angular or round figure, as well as its degree of moisture, produce very considerable differences in the several kinds of mortars. Clay baked into bricks, or pouzzalana, which is clay baked by volcanic fires, and altered by exposure to air, are likewise added to lime in the making of mortar.*

* Consult Les recherches de M. de la Faye, sur la preparation que les romains donnoient à la chaux, Paris 1777 & 1778, the first and second parts. F.

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Though lime, as well as siliceous earth, be perfectly infusible alone; yet if they be heated together, the proportion of the former being much the greatest, they melt, as has been observed by Messrs. D'Arcet and Gerhard. Lime likewise serves as a flux to one third of its weight of clay: it appears to have a stronger affinity with this earth, than with silex, as Kirwan informs us. The mixture of these three substances melts still more easily and completely, than lime with either of them singly; so that one part of lime and one of clay, will serve to fuse two parts, or even two and a half of siliceous earth: this fact shews the cause why many hard stones giving fire with steel, and of a quartzose nature, melt when exposed to a strong heat; the combination, or simple mixture of calcareous earth and clay, is the cause of their vitrescibility.

The mutual action of lime and ponderous earth is not yet known.

One part of calcareous earth enters into fusion with half a part of magnesia: the glass, formed by this mixture, afterwards dissolves, and completely melts a quantity of siliceous earth, equal to the lime it contains; equal parts of siliceous earth, magnesia and lime, melt therefore by heat into a perfect glass.

The intimate nature of lime is not known. The early chemists, desirous of explaining, by
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physical reasoning, the phenomena exhibited by lime in its combinations, and more especially in its extinction, referred its cause to the particles of fire fixed in the calcareous stone during its calcination. This was the theory of Lemery. M. Meyer did not admit that pure fire was capable of combining in this manner, and therefore asserted, that it existed in lime united with a peculiar acid: this subtle kind of sulphur was the *acidum pingue*, or the *causticum* of this chemist; but his doctrine, though occasionally brought forward under different names, has been overthrown by a series of experiments, which have completely shewn its falsity. Many modern chemists believe, that the matter of heat exists in a combined state in lime, and that the light perceived by Meyer and Mr. Pelletier, with the ebullition, the evaporation of the water, and the peculiar smell during the extinction of the lime, are consequences of its disengagement; but this opinion must continue to be merely hypothetical, till it shall be demonstrated that heat, considered as matter, exists in all those phenomena, which may be well explained, by considering it as nothing more than a modification of bodies. These observations shew, that the principles and composition of lime are yet unknown, and that we cannot, with any certainty, decide whether it is the product of an attenuation, or peculiar preparation

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tion of the vitrifiable or argillaceous earths ; though that opinion appears probable to some of the greatest naturalists. It cannot in fact be doubted, but that it is formed by marine animals, and that its constituent parts are united and combined in the water, during the life of these organic beings ; but nothing further can be added on the subject, which deserves the attention of such as dedicate themselves to studies which demand accuracy, and who prefer the knowledge of facts to mere supposition.

Lime is employed in a great number of arts, and especially in building. In medicine, diluted lime-water is administered with success, in the cure of ulcers, &c. it has been esteemed as a powerful lithontriptic ; but repeated trials have shewn, that it is not always attended with the desired success, and that its use, long continued, produces an alteration in the animal fluids of a scorbutic or septic nature.

C H A P. III.

Genus II. Alkaline Salts.

WE place alkalis before acids, because they appear to be more simple, less easily decomposed, and resemble the salino-terrestrial

terrestrial substances in their properties. They have a urinous, burning, and caustic taste; turn the syrup of violets to a green; give out heat on being united with water; absorb the acid contained in the air; dissolve earths; and have a strong tendency to combination. Three species of alkalis are known; vegetable fixed alkali; mineral fixed alkali; and volatile alkali.

Species I. Vegetable fixed Alkali.

Vegetable fixed alkali is so denominated, because it is found in large quantities in the vegetable kingdom, though it is likewise found in the mineral kingdom; it is usually called salt of tartar, or pot-ash, because these two substances greatly abound with it. The vegetable fixed alkali, in a state of purity, was not known before the discoveries of Dr. Black.

This salt, when pure, is dry, solid, and of a white colour; its taste is so strong, that it destroys the texture of the skin. It instantly converts the colour of syrup of violets to a much deeper green, than lime-water produces in that substance, and this green is quickly destroyed and converted to a brown yellow.

The action of light on the vegetable alkali is not known.

Exposed

Exposed to heat in closed vessels, it soon becomes soft, and melts at the commencement of ignition; if it be then poured out on a smooth stone, or metallic plate, it concretes into an opaque brittle mass. It is not decomposable by heat, and because it is not volatilized, except in a very strong heat, such as that of a glass-house, it is called fixed. It dissolves a portion of the earthen vessels in which it is heated.

Exposed to the air, it strongly attracts humidity, becoming liquid, and gradually assuming the state of a neutral salt, by combining with the acid of the atmosphere. This is the cause of the augmentation of weight, and the property of effervescing with acids, which it acquires by such exposure. To preserve it in a state of purity, it must be kept in well closed vessels, entirely filled with it.

The vegetable fixed alkali dissolves in water with great facility, producing at the same time a high degree of heat, and exhaling a fetid lixivious taste: its solution is colourless, and affords no precipitate, when the salt is very pure. If it be desired to separate it from its solvent, the water must be evaporated to dryness, in closed vessels; for if the operation be made in open vessels, it attracts the acid contained in the air, and becomes effervescent. This absorption is so rapid, that it is scarcely possible to leave the solution of this salt exposed to the air, without

out its being partly neutralized: the same alteration takes place if it be kept in a bottle, which it only fills in part, and which is often opened.

In the dry way it combines with vitreous or quartzose earths, and forms by fusion the transparent body called glass. This body has different properties, according to the relative quantities of sand, and fixed alkali it contains. If two or three parts of salt be used to one of earth, a soft glass is produced, which attracts the humidity of the air, becomes opaque, and at last fluid. This glass is soluble in water, by virtue of the superabundant alkali it contains; and the solution is called liquor of flints: in process of time it deposits a portion of the earth it contains, in white semi-transparent flakes, of a mucilaginous appearance, and so light, that they subside very slowly. Acids seize the alkali, and precipitate the earth. In order that this precipitation may be well performed, the liquor of flints must not be too much diluted; for in this case the particles of earth are in a state of such extreme division, that they remain suspended in the liquid, which must be evaporated, before any sensible subsidence can take place. Several chemists think that the earth of flints, thus obtained, has been changed in consequence of its union with alkalis; they imagine that it resembles argillaceous earths, and is capa-

ble of uniting with acids, and forming argillaceous salts: this was the opinion of Pott and Beaumé, but Scheele has shewn, that this soluble portion of the earth precipitated from the liquor of flints, is obtained from the vessel of clay in which the quartzose earth and alkali are fused.

The art of making glass, is a process entirely chemical: the purity of the two substances, their proportion, and their complete fusion, by the application of heat sufficiently strong and long continued, are conditions indispensably necessary for producing glass, which shall be hard, transparent, without bubbles, and unalterable in the air. We shall hereafter have occasion to take notice of different substances added to the sand and alkali, to increase their fusibility, and to produce glass of a due degree of weight, transparency, and other properties adapted to the use it is intended for.

Fixed vegetable alkali does not act so strongly on pure clay, as on quartzose earth; but the difference has not been accurately ascertained.

This salt appears capable of combining with ponderous earth, magnesia, and lime; but these combinations have not been much inquired into.

Though the vegetable alkali has not yet been decomposed, yet there are many facts which tend to shew that it is not a simple substance.

substance. Stahl, who considered the simple salts as products of the union of water and earth, imagined that fixed alkali differs from acids, only in its containing the latter or earthy principle more abundantly; from this consideration he explained its dryness, and other distinctive properties. It is probable that vegetable alkali, as well as all other salts, consists of a combustible body, united with air; since Rouelle has observed, that vegetables, by burning, afford more alkali than in their natural state. This alkali, in many cases, acts like acids, which are known to contain pure air in large quantities; for it calcines metals, burns combustible matters, &c. We do not however propose this but as an hypothesis not yet proved, though it may serve to explain several facts.

The vegetable fixed alkali is employed in surgery to corrode the skin, and to produce inflammation and suppuration in certain cases.

Species II. Mineral fixed Alkali.

The name of mineral fixed alkali is given to a saline substance, which possesses the same general characters as the foregoing, and is found in great quantities united with a peculiar acid salt, in the waters of the sea, and in many springs. It is likewise obtained from vegetables, though much less frequently than the preceding. This salt has

been called marine alkali, because it is one of the component parts of marine or common salt; it is also called salt of soda, because it is most frequently obtained from that plant. The mineral fixed alkali, when pure, has as strong and as caustic a taste as the vegetable alkali; it produces an equally intense green in syrop of violets: its form is dry and solid.

It melts at the commencement of ignition; a violent heat volatilizes it; it acts on almost every kind of vessel in which it is heated.

Exposed to the air of the atmosphere, it attracts the humid vapours, as well as the aerial acid, and gradually becomes neutralized. The action of the oxygenous principle, or vital air, on this salt, is not known.

It dissolves in water, producing heat, and emitting a fetid lixivial odour. Evaporation in closed vessels, is the only method of recovering it in a state of purity from its solution; and for the same reasons as were mentioned in treating of the vegetable alkali, it must be preserved in well closed vessels entirely full.

The mineral fixed alkali combines readily with vitrifiable earths in the dry way, and forms glass. Glass-makers have observed, that this salt produces a more fusible and solid glass than the vegetable alkali; for which reason they prefer it in the manufacture of that commodity. Lastly, this alkali,

kali, like the vegetable fixed alkali, combines with acids, and with a great number of bodies hereafter to be treated of.

From these properties it may be observed, that the difference between the two fixed alkalis, in a state of purity, is not very considerable, and that their respective properties can only be known with certainty, from their combinations. When united with the same acid they produce neutral salts exceedingly different in all their properties; a circumstance which seems the more singular, as it is absolutely impossible to point out any difference between them in their pure and caustic state. Bergman adds, as a distinguishing property of these two salts, that their affinity with acids is not the same; that of the vegetable fixed alkali being the stronger, so that it is capable of decomposing salts, whose base is the mineral alkali. This subject will again come under examination, when we speak of secondary salts.

The intimate nature or composition of the mineral fixed alkali, is not more known than that of the vegetable fixed alkali.

It is used in the making of glass, soap, and other compounds.

Species III. Volatile Alkali.

The volatile alkali is distinguished from the two foregoing, by its strong and suffocating smell, and its singular volatility.

Like

Like the fixed alkalis, this salt was not known in its state of purity, before the ingenious experiments of Black and Priestley; that which was considered as such, is a species of imperfect neutral salt, in a solid and crystalized form, possessing some of the properties of volatile alkali, but really composed of two saline substances: the character or property of effervescing with acids, which was formerly attributed to the volatile alkali, belongs only to this neutral salt.

The liquid known in chemical laboratories, by the name of caustic, or fluor volatile alkali; and in pharmacy, by that of volatile spirit of sal ammoniac; consists of this alkali dissolved in water. Dr. Priestley has shewn, that by the help of a gentle heat, this liquor may be made to give out a permanent gas; and that the water deprived of this gas, loses its alkaline properties. This aeriform fluid is the pure volatile alkali, and is known by the name of alkaline gas. Macquer has well observed, that this body must be examined, in order to arrive at a knowledge of the properties of the volatile alkali.

To obtain this elastic fluid, a certain quantity of the alkaline spirit is put into a small retort, or matrafs of glass. A recurved tube is adapted to this vessel, and the extremity of the tube is plunged beneath the mercury

mercury of a pneumato-chemical apparatus; a vessel of glass filled with the same metallic fluid, being inverted over its orifice. The bottom of the retort or matrafs is then heated, by means of burning charcoal, or the flame of spirit of wine. The first portion of elastic fluid, consisting chiefly of the common air contained in the vessel and tube, is suffered to escape, and when the ebullition of the fluid is strong, the gas is to be collected. The distillation must not be urged, so as to cause the water to pass in the form of vapour, or a small vessel should be affixed in the middle of the tube of communication, which being kept cool, may serve to condense the aqueous vapour, and causes the alkaline gas to pass in a very pure and dry state.

The alkaline gas, obtained by this process, resembles air in its transparency and elasticity, as long as it is kept above the mercury. It is rather lighter than the air of the atmosphere; its smell is penetrating, and its taste is acrid and caustic; it readily and strongly changes the blue colour of violets to a green, but the alteration produced, is less than when pure alkalis are used; it destroys animal life, and corrodes the skin, if exposed for some time to its action.

Though it is incapable of maintaining combustion, and extinguishes bodies which are already on fire, yet it increases the magnitude

nitude of the flame of a taper before extinction, producing a pale yellow colour round its edge, which proves that alkaline gas is partly inflammable.

It is absorbed by porous bodies, such as charcoal, sponge, &c.

Priestley has discovered, that the electric spark passing through alkaline gas, increases its volume to three times its former quantity, and changes it into inflammable gas; the cause of this change is not yet known. But it seems that the alkaline gas is decomposed in this operation.

Alkaline gas is one of the elastic fluids which are the most susceptible of dilatation by heat.

Atmospheric air does not combine with alkaline gas, but only mixes with and dilutes it: the action of vital air on this gas has not yet been examined.

Water quickly absorbs alkaline gas; if the water be frozen, it immediately becomes fluid, and produces cold; whereas, on the contrary, fluid water becomes heated by combination with this gas. Water saturated with gas is known by the name of fluor and caustic volatile alkali: we apprehend that this solution may be called volatile alkaline spirit, in the same manner as the solution of marine acid gas is called spirit of salt. We shall hereafter see that the strongest and most

most pure alkaline spirit is produced by saturating distilled water with this gas.

Alkaline gas has no sensible action on earths, or on the salino-terrestrial substances. Its action on acids, and many neutral salts, is very considerable.

The alkaline spirit has the same properties as the gas it holds in solution, but not in so eminent a degree; because the gaseous being much less strong than the fluid aggregation, the tendency to combine, will, according to one of our laws of affinity, be much more strong in the gas than in the alkaline spirit.

Volatile alkali has been considered as a combination of fixed alkali with a combustible substance. This conjecture was founded on the consideration that volatile alkali is produced in many circumstances by heating fixed alkali with inflammable matters; but it was not known whether the fixed alkali entered as a principle into the composition of the volatile alkali, or whether it did not afford a peculiar principle, which, by combining with a portion of combustible matter, produces that salt. Our knowledge respecting the nature of volatile alkali is at present somewhat more extended. The fine experiment of Dr. Priestley, who changed alkaline gas into inflammable gas, by the electric spark, has caused several chemists to suspect that the latter is one of the prin-

ciples of volatile alkali. Mr. Berthollet, by a series of experimental inquiries, has succeeded in proving that this salt is a composition of aqueous inflammable gas, and atmospheric mephitic or phlogisticated gas. He was led to this conclusion by the action of dephlogisticated or aerated marine acid on the alkaline spirit, by the decomposition of ammoniacal nitre in closed vessels, and by the reduction of metallic calces effected by means of alkaline gas. These facts will be exhibited more at length in the history of the compound substances to which they relate. We shall confine our observation in this place to the facts, that when combinations of the calces of copper and of gold are heated with alkaline gas, water and phlogisticated gas, or atmospheric mephitic are obtained, and the metals are reduced. In these operations the volatile alkali is decomposed, its inflammable gas seizes the vital air of the metallic calces with which it forms water; the metals remain pure, and the phlogisticated gas, or atmospheric mephitic, the other principle of volatile alkali, is set at liberty. From these experiments, of which we shall, in the course of the present work, give a more ample account, Mr. Berthollet concludes, that volatile alkali contains six parts of atmospheric mephitic, and one of inflammable gas.

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The volatile alkali, diluted with water, is used in a great number of disorders; it is aperient, and powerfully incisive. It acts strongly on the skin; it is prescribed as a remedy for the bite of vipers, and for cutaneous, and venereal disorders, &c.

As this substance is acrid and caustic, it ought not to be used, but with particular care. Externally applied, it is found exceedingly serviceable in discussing tumours, especially such as are formed by coagulated milk, lymph, &c. It readily cures burns, and is often and successfully employed in the cure of chilblains, &c. It has been constantly used under different names, as a very active stimulant in syncope, apoplexies, &c. Its use in the latter case ought to be in very moderate quantities; it is not prudent to administer it internally, without previous dilution in a considerable quantity of water. Dangerous excoriations have been produced in the oesophagus, and the membranes of the stomach, by the volatile alkali being given without this precaution.*

* M. de Morveau proposes to call the vegetable fixed alkali by the name of pot-ash (potasse); the fixed mineral alkali by the name of soda (soude); and the volatile alkali by the name of ammoniac. These denominations have the advantage of rendering the nomenclature of neutral salts uniform and easy. Consult our second volume. F.

